Technology, Public Policy, and the Changing Structure of American Agriculture

Volume II—Background Papers

Part E: Agricultural Research and Extension, Agricultural Structure, and Environment and Natural Resources

1. Agricultural Research Policy: Its Evolution and Current Issues
2. Agricultural Extension Policy: Its Evolution and Current Issues
3. Economic Impact of Agricultural Research and Extension
4. Agricultural Research and Extension Policy: Contemporary Issues
5. Agricultural Structure Impacts of Emerging Technologies
6. Environmental and Natural Resource Impacts of Emerging Technologies in American Agriculture

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Paper No.

1. Agricultural Research Policy: Its Evolution and Current Issues by Roy L. Lovvorn

2. Agricultural Extension Policy: Its Evolution and Current Issues by George Hyatt

3. Economic Impact of Agricultural Research and Extension by Fred C. White

4. Agricultural Research and Extension Policy: Contemporary Issues by Ronald D. Knutson

5. Agricultural Structure Impacts of Emerging Technologies by Thomas L. Sporleder

6. Environmental and Natural Resource Impacts of Emerging Technologies in American Agriculture by James Hite

Background Paper No. 1

Agricultural Research Policy: Its Evolution and Current Issues

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Office of Technology Assessment
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GLOSSARY

APHIS	Animal and Plant Health Inspection Service
ARS	Agricultural Research Service
CSRS	Cooperative State Research Service
ES	Extension Service
ERS	Economic Research Service
SAES	State Agricultural Experiment Stations
SCS	Soil Conservation Service
USDA	United States Department of Agriculture

SUMMARY

Recent developments in the biological sciences, and especially in genetics and molecular biology, have created greater challenges within the agricultural research institutions and are expected to offer some fundamental breakthroughs in the development of new knowledge in both the animal and plant worlds.

1. The Joint Council on Food and Agricultural Sciences and a National Research and Extension Users Advisory Board are expected to have an even larger role in research planning in the future.

2. The Agricultural Research Service will continue to serve as the national research leader in the biological and engineering fields of agriculture. Their relationship to the land-grant universities must be preserved. Hopefully their latest reorganization will suffice for a while for the sake of morale within the ranks of the scientists.

3. The agricultural experiment station will continue to be the research arm of the land-grant university of 1862. These institutions are in a unique position to utilize the research potential of biotechnology developments, provided they strengthen their biological science departments. Federal formula funding will be necessary, but more grant funding will be essential to enable the stronger ones to become centers of excellence and make maximum contributions toward greater efficiency in agricultural production.

4. The role of the land-grant universities of 1890 must be redefined. To focus their research on problems of the small farm and disadvantaged would seemingly be a logical consideration for the policy makers.

5. Recent developments in biotechnology has altered the historic relationship between public and private research institutions. Policy makers have not given sufficient attention to the full implications of these developments.

I. OVERVIEW OF THE AGRICULTURAL RESEARCH SYSTEM

Organized agricultural research had its beginning in Scotland and Germany, and the concept was introduced to the United States by Samuel Johnson in 1855. Legislative landmarks were the passage of the Organic Act of 1862, establishing the United States Department of Agriculture, and the Merrill Land-Grant College Act of 1862, creating the land-grant college system. Congressional support for agricultural research began in 1856 when the appropriation bill provided for the collection of agricultural statistics, investigations for promoting agriculture and the rural economy, and the procurement and distribution of cuttings and seeds. As research was expanded, the work was organized into bureaus, primarily along commodity lines, from 1884 until 1931. The Bureau of Agricultural Economics eventually became the Economic Research Service. The other bureaus were abolished in 1953 and their functions transferred to the Agricultural Research Service (5). Today ARS has a budget of $474,278,000 and a staff of 2,850 scientists. The Economic Research Service has a budget of $44,000,000 and a staff of 500 scientists, not all of whom are engaged in research.

The Hatch Act of 1887 provided for federal funds to support research within the states and proved to be the real beginning of the state agricultural experiment stations. Prior to that date a few states had established experiment stations with local support, and within a few years all the states had established such institutions. The Adams Act of 1906, the Purnell Act of 1925, the Bankhead-Jones Act of 1936, and the Research and Marketing Act of 1946 further strengthened the state research programs. The Act of 1955 consolidating the Hatch Act reinforced the interest of the Congress to continue to encourage and support agricultural research at the state stations. The territories of Alaska, Puerto Rico and Hawaii were also included in the system with this Act. Other territories were included between 1970 and 1982.

As appreciation for research developed, state legislatures increased their support and today Hatch funds account for less than 20 percent of the local research budgets. The 1984 budget for CSRS is $247,655,000. Of this amount $147,486,000 is allocated to the SAES on a formula basis and $22,159,000 is allocated to the 1890 universities on a formula basis as designated by the Evans-Allen program. Hatch funds must be matched by the states. Evans-Allen funds carry no such requirement. The remainder of the CSRS budget, less 3 percent for administration, is appropriated for special and competitive grants. The SAES now employes 6,600 scientists years.

The agency for administering the Hatch funds was called the "Office of Experiment Stations" for many years, later was placed within the ARS, but since 1962 has been a separate agency, administering these and other funds appropriated for research at both the 1862 and 1890 land-grant universities.

II. WHY RESEARCH?

Modern technology is producing agricultural surpluses of many commodities. Why then should research be supported? Research is an investment for tomorrow, and to unravel the mysteries of nature requires time, support and imagination. Research programs must be continuous to be successful. Scientific achievements are built upon a continuous and adequately supported program.

World population continues to increase and research must be geared to meet future, not present needs.

Not all research is production oriented. Such subjects as human nutrition, marketing, and studies on behavior and motivation are not directly related to problems caused by surpluses. Neither is utilization research. In fact, much of such research is designed to help eliminate surpluses.

Many research problems are never solved, only progress is made. New varieties become susceptible to new strains of diseases and insects. As progress is made in one area of research, problems arise because of such developments and so investigations must be a continuing process.

III. ROLES OF FEDERAL INSTITUTIONS IN THE SYSTEM

An Assistant Secretary for Science and Education has been named and all evidence indicates much better coordination among the agencies and between the USDA and the land-grant institutions.

The National Agricultural Research, Extension, and Teaching Policy Act of 1977 and amended in title XIV of the Agriculture and Food Act of 1981 strengthened the role of the Secretary in the coordination and planning of agricultural research, extension and teaching. The Act also designated the USDA as the lead agency of the federal government for agricultural research. The Act provided for the establishment, jointly with the Secretary of Health and Human Services, procedures for coordination with respect to nutrition research. In order to bring about better coordination and planning a Joint Council on Food and Agricultural Sciences and a National Agricultural Research and Extension Users Advisory Board was provided in the Act. Both groups have been organized and are now functioning (4).

Areas needing additional research and extension emphasis were specified in the Act, and provisions made for competitive grants, special and facilities grants, animal health, energy, small farms and aquaculture. Funds for facilities within the states is now restricted to the 1890 institutions. By law these institutions are entitled to 15 percent of increases in Hatch funds.

The primary federal institutions responsible for agricultural research are the Agricultural Research Service (ARS) and the Economic Research

Service (ERS), both within the USDA. From the inception of federal legislation for support of research at the national level and at the state level there has been a certain amount of competitiveness as well as cooperation. A committee of Agricultural Research Service administrators and State Agricultural Experiment Station directors agreed in 1960 on the following division of responsibilities (1):

1. The Agricultural Research Service and the State Agricultural Experiment Stations are individually responsible for accounting for the research results from the monies appropriated or allocated to them.
2. The ARS is primarily responsible for research on problems of national and regional concern to agriculture and on those problems involving relationships between the United States Government and the governments of other nations.
3. The State Agricultural Experiment Stations are primarily responsible for research on problems within the borders of their respective states, and for such regional research as is of importance to the area. Statements 2 and 3 were not intended to be mutually exclusive.
4. Basic research is a responsibility both of the ARS and the SAES in each institution and in each area so far as feasible.
5. The ARS and the SAES will cooperate on a voluntary basis in research whenever cooperative action will be more effective than separate action, and that regional research will usually be cooperative.
6. Joint planning should be an essential phase of cooperation.
7. ARS and SAES will continue to share facilities to the extent that their respective primary responsibilities permit.
8. ARS and SAES will examine each of their locations with respect to effective concentration of federal and state personnel.

9. To the fullest extent practical, necessary adjustments in ARS farm research at field locations be fully explored with the experiment station director before such actions are taken.
10. Negotiations on cooperation be conducted between state station directors and directors of ARS research divisions.
11. ARS facilities be located at or adjacent to land-grant colleges unless there are appropriate and compelling reasons for other locations.

These ground rules clarified the relationship that had existed since the inception of the system, and basically cooperation between the ARS and the state stations has been excellent. The general assumption, however, of assigning national and regional responsibilities to ARS and state and regional responsibilities to the states become ambigious at times.

Agricultural Research Service

In 1972 ARS was reorganized into four geographic regions, thus abolishing to a large extent the national leadership that had existed at Beltsville. This change was looked upon favorably by station directors because of better communication, but unfavorably by the scientists, both within ARS and at the state stations, because both groups appreciated the national leadership that had existed. Since that time ARS has made several adjustments in an attempt to remedy that criticism.

In response to criticism and in an attempt to increase their productiveness, the ARS in 1983 announced a reorganization plan whereby their areas were reduced from 24 to 11, and other administrative changes implemented that resulted in 300 positions being moved from management to research. They estimate that an additional $8,000,000 will now be directed toward research. Their 14 percent for overhead has been reduced to 10 percent.

The recent changes within ARS has streamlined their administration, reduced the role of area and regional offices, and strengthened the Administrator's office in decision making including priority setting and budget preparation. The national program staff has been reduced, thus tending to give them more administrative responsibilities but diluting their role of interacting with the scientists. They have, however, been given greater responsibilities in terms of budget justification and preparation. Their role as national research leaders has been strengthened administratively but weakened in terms of their interactions with the scientists.

Area directors now report to the Administrator, whereas previously they had reported to the Regional Administrator. Most of the functions previously performed in the regional office have been transferred elsewhere, so in reality there are no longer viable regional offices. These changes are recent and time will determine their effectiveness, but the question could be raised as to why the previous four regional offices should not be located in Washington.

Another weakness in the "national" role of ARS is their practice of locating scientists at the land-grant universities. Both instutitions like this practice. The ARS scientists enjoy the professional association on a university campus, including the opportunity to direct graduate student programs, and state stations enjoy and appreciate the complimentarity of the ARS supported programs. The end result is a productive research program that is very beneficial to the local station, but some of limited regional or national significance.

Agricultural research in the U. S. is facing some unusual opportunities following recent developments in genetics, molecular biology and other developments in the biological sciences. To realize the potential, however,

will require some fundamental changes in the organization of public institutions.

Historically ARS has been responsible for national and regional research and the SAES for local and regional. Such a delineation of responsibilities permits a broad area in which both can operate. ARS has a logical role in national laboratories such as the Plum Island Animal Center, plant introduction centers and others with regional and national responsibilities, and with the regional utilization laboratories. This is not to suggest that ARS activities within the state universities should be abolished. The ARS-SAES scientists function in a complementary way and has proven to be very productive. To perpetuate and strengthen this working relationship at the state level makes it even more necessary that planning and priority setting remain an important function of ARS at the national level and that the Joint Council and Users Advisory Board continue to be recognized as essential.

Clientele is defined as the user of the system. The ARS clients fall into four categories, namely, serving (1) other federal agencies such as APHIS and SCS, (2) business firms interested in product development at the regional utilization laboratories, (3) public user groups, and (4) maintaining a relationship with foreign governments. In a sense the SAES are also their clientele because of the latter's interest in and dependence on the ARS for germ plant collection and preservation, both plant and animal, and of providing many other services not appropriate to the states.

Economic Research Service

The Economic Research Service deals primarily with economic and policy issues of national and international significance. Their functions are divided between research and service to the policy makers within the Department of Agriculture. A recent decision has been made to locate all ERS

scientists in Washington, thus removing them from university campuses. The rationale is valid in terms of the ERS role in servicing the policy makers of the Department. It is probably not valid in terms of recruiting and maintaining a prestigious group of economists for research. The decision to locate all scientists in Washington will have a negative impact upon the agency's ability to recruit and maintain a prestigious corps of scientists. The impact of university economists on ERS economists is certainly a positive one and such influence will be lost once they are removed from the campuses.

Office of Grants and Program Systems

The Office of Grants and Program Systems under the Assistant Secretary of Agriculture for Science and Education has the role of administering competitive grants for agricultural research. Eligible participants include all scientists, be they in public or private institutions. The rationale for a separate office is to assure that grants are made on an impartial basis. The Office is the logical one to administer grants in biotechnology and other basic sciences so necessary in modern agricultural research. Funds should be increased to offer substantial support on a competitive basis for work in basic grants, including biotechnology; but, individual grants must be larger than is the current practice. Other federal granting agencies should also continue to support work in the basic sciences at the land-grant universities.

Cooperative State Research Service

The Cooperative State Research Service had its beginning functionally with the passage of the Hatch Act in 1887 and the creation of the Office of Experiment Stations to administer the federal funds to the SAES. The goals of the agency are to (1) represent the interest of Congress and the Secretary of Agriculture, and explain the position, desires and needs of the Department

of Agriculture to the SAES system; (2) participate in state and federal research priority-setting processes and decision making; (3) maintain and promote efficiency and coordination among the SAES system using federal funds; (4) promote and encourage scientific excellence in institutional research programs; and (5) communicate the achievements, priorities, and needs of the state and national agricultural research system to the Congress, to the USDA and to the public (6). The role of this agency has been modified from time to time, but is primarily (1) one of representing the states within the Department on matters affecting them and particularly in the preparation of the federal budget, and (2) one of performing a coordinating role and of assisting the states. The latter is done through a process of institutional reviews that utilize invited scientists from other institutions to participate.

Their personnel ranks have been so reduced to the extent that much of their time is devoted to necessary but mundane matters of budget preparation rather than providing scientific leadership. The role of CSRS should be strengthened to give it more expertise in the field of science and become an accepted spokesman in the USDA for the SAES. Its role can be much larger than budget preparation and bookkeeping.

Other Federal Agencies Supporting Agricultural Research

The National Science Foundation, the National Institutes of Health, the Environmental Protection Agency, and to a lesser extent the Department of Defense, support research of interest to the agricultural community. The EPA is playing a vital role in engaging in research itself as well as supporting research at the land-grant universities in areas of interest to agriculture. As more is learned of environmental problems affecting agriculture, the role of EPA will undoubtedly increase. The newness of the

EPA-SAES relationship has not been without administrative problems but should improve with experience.

The National Science Foundation and the National Institutes of Health have supported basic research at the universities and the extent to which SAES have participated depends upon where they have placed their emphasis. Some of the stronger ones depend heavily upon such support. As land-grant universities move into biotechnology, they will need to develop a staff that qualifies for and draws upon the resources of these two federal agencies.

IV. ROLES OF THE UNIVERSITIES IN THE SYSTEM

Higher education in the U. S. covers a broad spectrum, including the classical universities, the land-grant university of 1862 and 1890, and other universities offering agriculture curricula but with limited research.

Land-Grant Universities of 1862

The state agricultural experiment stations are the research arm of the Colleges of Agriculture of the land-grant universities of 1862. Their role is to generate knowledge that will serve as a basis for the production and utilization of food, fiber and shelter for all of the citizens of the state. Although some research was initiated following the passage of federal legislation creating the 1862 land-grant universities, the real impetus for expanded research came with the passage of the Hatch Act of 1887. This legislation resulted in the eventual establishment of an agricultural experiment station in each state. Present research programs include resource conservation and use; protection of forests, crops and livestock; efficient production of farm and forest products; product development and quality; efficiency in the marketing system; expanding export markets and assisting developing nations; consumer health, nutrition and well-being; raising level

of living of rural people; and improving community services and environment. As institutions have grown, programs have expanded, institutional structure has changed, but the basic goals have not.

Funding for regional research was provided in the Research and Marketing Act of 1946. This legislation provided a formal mechanism for two or more states to cooperate on research of common interest. Up to 25 percent of the Hatch funds can be used for such purposes, and in actual practice the percentage has been greater. Although regional research has made significant contributions to agricultural development, its potential has never been fully realized. The regional funds have tended to become an integral part of the station budget, thus eliminating the financial incentives for the researcher.

The role of the station is fulfilled by a staff of competent scientists who may be full-time researchers, joint with teaching, or joint with extension. Originally they constituted a separate body of full-time researchers, but during the past 50 years the trend has been toward joint teaching and research responsibilities, and during the past 10 years many of the younger faculty members have joint extension-research, extension-teaching or in some cases extension-research-teaching appointments. ARS personnel also participate in the graduate training program.

The SAES should play a key role in future research provided certain changes are made. The administrative structure of providing close working relationships between the biological sciences and traditional agricultural research departments should enable the latter to build upon the former, a necessity if full potential of biotechnology is to be realized. This arrangement will necessitate much better support for the biological sciences than now exists in many of the land-grant universities. The land-grant concept

of teaching-research-extension is unique, not perfect, but is the best system so far designed. It should be preserved and strengthened.

Formula funds is necessary for the maintenance of a permanent staff at all of the land-grant universities, but all cannot strive to become centers of excellence, at least not in all fields.

The land-grant universities will continue to do research in both basic and applied fields and the major source of their funding will continue to come from local funding. The extent of the applied program will depend upon the local funding and commitments. The real breakthrough in research will come through the stronger institutions supported through national grants. This is not to say that all land-grant universities will not benefit from such basic research. Much of the applied work will be size of farm neutral, but emphasis must continue to be directed toward work applicable to small operators, not only in technology but in understanding motivation and poverty usually associated with the economically depressed.

The clientele for the SAES is all of the citizens of the state. Initially the stations focused on questions facing farmers, and although they still work on farm problems, their current mission is much broader. The complex interactions of industrial development with environmental problems necessitates both basic and applied research directed toward problems facing consumer groups as well as farmers themselves. The primary client of the SAES is the extension service because that is the agency that extends the knowledge generated through research.

The question of agricultural research as related to farm size is being discussed in a separate paper (7).

Land-Grant Universities of 1890

The role of the land-grant colleges of 1890 has also evolved with time. Originally they were created to provide college training for black students, and for nearly a century they had essentially no support for agricultural research. There is still little state support. Beginning in the 1960's the Department of Agriculture allocated part of their grant funds under PL-89-106 to the predominately black institutions. These funds, while limited in the beginning, have gradually increased, and with the passage of the Farm Bill of 1979 these institutions were assured a percentage of the increases under the Hatch Act. The original rationale for their research was to study problems unique to small farmers, and although they still engage in this type of activity, they are not restricted to such limitations.

Congress appropriates the money that is allocated by formula by CSRS directly to the 1890 institutions with a provision for joint program planning with the agricultural experiment station within the state in question.

Originally the role of the land-grant universities of 1890 was to train black students and conduct research applicable to small operators. Neither role is particulary appropriate today. Any qualified student can attend an 1862 institution regardless of color or economic background. Also, the 1890 universities are actively recruiting white students and faculty, some by court decree. As their funds for research have increased at 1890 universities, they have expanded their programs so that no longer a unique role is evident. At the same time cooperation with the 1862 institution within the respective state has lessened. The rationale for their support must rest on culture, tradition, and politics, not in serving the black community.

Although CSRS insists upon a submission of a joint program within a state between the 1862 and 1890 institutions, the procedure is ineffective

in developing cooperation between the two institutions. Legislation may be needed, as well as a stronger administrative stance, in working toward more efficient use of federal funds within a state.

Another option would limit the research funding to projects specific to the small farm or to the disadvantaged, as originally justified to the Congress. These institutions have the background to understand and appreciate the need for research in areas that have not been addressed by the 1862 institutions. Such an assignment of functions would strengthen the research activities of both the 1890 and the 1862 institutions within a given state.

Non-Land-Grant Agricultural Universities

The non-land-grant agricultural universities' role has also evolved with time. Although their role is primarily teaching, a few of them have developed effective research programs. They are eligible for USDA competitive grant funds as well as other governmental grant monies, but their total contribution to agricultural research in this country is relatively minimal. These institutions will continue to play a role in fundamental research and should continue to be eligible for grants on a competitive basis, but the best returns on the investment of public funds will come from biological departments associated with agricultural departments.

Classical Universities

With modern developments in the basic sciences the classical universities, both private and public, are interested in and capable of making a contribution that will be of interest to agricultural development. Their excellent faculties in chemistry, biochemistry, botany, zoology, microbiology and genetics are now seriously engaged in scientific research in support of biotechnology. They will no doubt continue to play an important role.

V. RESEARCH PLANNING AND PRIORITY SETTING

Establishing research priorities at public institutions is both complex and continuing. The dual support of SAES by federal and state funding necessitates that priorities serve both local and national needs. Priority setting processes in the SAES were discussed in an Office of Technology assessment publication in 1982 (2). The author outlined four steps in the process. First, to identify the research programs of greatest need and value to the state, its people and to the nation. Second is to examine the scientific and practical feasibility of those investigations relative to the resources available. Third is to set priorities with due consideration to needs. Fourth is to respond by initiating and completing those researches given priority.

The extent to which priorities have been successful depends upon the critics. The mechanism for establishing local priorities usually consists of state advisory committees and feedback from extension personnel. This has the bias that the committees are often "friends of the establishment" and do not necessarily reflect the real needs of the masses. Also, special interest groups are capable of obtaining state funds for research with or without the blessings of the SAES. Environmental and consumer groups have received more consideration in recent years. Even with these limitations, the public has received good returns from such investments.

The Joint Council on Food and Agricultural Sciences (Joint Council) and the National Agricultural Research and Extension Users Advisory Board (Users Advisory Board) were created by legislative action to aid in improving planning and coordination between the USDA, other federal agencies, land-grant universities, and other public and private institutions. The concept is a beautiful one. Information is fed to these two committees from the states through regional planning committees and directly from the research agencies of the USDA.

Initially, it was difficult to see much progress and time was required for the mechanism to mature, and currently there is much optimism in

believing better planning is being achieved. It is expensive, but obviously a mechanism must be retained for preserving the partnership in research between the federal and state institutions, and it seems to be the best conceived to date.

VI. PRIVATE SECTOR INTERRELATIONSHIPS

Relationships with the private sector have developed somewhat differently at the state level as compared to the national level. National commodity groups have maintained a close working relationship with ARS and so has the chemical industry in the development of pesticides.

Historically the ARS regional utilization laboratories have done the basic and early work in product development and has looked to the industry to make the necessary adaptations to consumer use. These relationships have been handled through patent protection and licensing arrangements, and presumably have worked satisfactorily for both parties.

Private support of research within the land-grant university system has evolved with time. In the early stages there were no funds from the industry. These institutions depended upon public funds entirely. With the expansion of agribusiness concerns a relationship between the two grew, but not without some growing pains. Following World War II with the introduction of pesticides a new era was entered in relationships between their producers and university researchers. The industry needed these products evaluated by public investigators, and hopefully "recommended". The industry was willing to put limited funds into such evaluations. SAES researchers with limited budgets and enthusiasm for these magic chemicals were willing and anxious to accept such funds. University administrators, anxious to protect the integrity of itself and its faculty, expressed some concerns, fearful that

pressure would be put on its faculty and also disenchanted with the pittance of some of the industrial grants. Memoranda of agreements have been developed that (1) resulted in larger grants and (2) defining in clear terms the roles and functions of the two parties. Although there were critics of the relationship by certain consumer groups, generally speaking the arrangement has served the public institutions and the public well.

Relations with the seed industry has changed as public research has expanded. Originally crop scientists tested varieties of their own creations as well as those developed by the industry. As the private seed industry expanded, publically supported research in varietal development decreased, and now SAES and ARS only work on the development of varieties of crops that are not of economic interest to the private industry. The emphasis of SAES-ARS scientists is toward the development of germplasm that can be used by the private sector in varietal development and release.

In the early days SAES published specific recommendations on many production practices. Today they tend to publish results and options for extension workers to interpret for their clients.

With developments in the field of genetics and molecular biology in more recent times a new era has been entered. New industrial companies have been organized, many headed and staffed by former university faculty. Some joint ventures have been formed between companies and universities. It is difficult to serve two masters, and this new relationship is one that must be critically observed. Obviously both types of institutions have a role to play, but joint ventures are looked upon with skepticism. A more wholesome arrangement will follow the traditional role of clearly defining public sector research that may be supported by the private sector, including patent rights (3).

VII. RESEARCH-EXTENSION INTERFACES

National support for research within the states began in 1887 and for extension in 1914. Extension is thus a logical step in the transfer of new knowledge. The Extension Service at the federal level has a similar relationship to the states as does CSRS. The relationship between ES and research agencies within the USDA is not so clearly defined. The ES extends federal research, but because of the nature of the agency this is not a very meaningful relationship.

The real significance of the relationship between research and extension exists at the state level. The land-grant concept of teaching-research-extension is most unique and has proven to be highly productive. However, it took time for the concept to become fully accepted. In the early days, even though the three functions were performed on the same campus, they were independent from each other and often in conflict. In the author's early days at one of the land-grant universities it was not unsual to see different recommendations on a specific subject by the research and extension workers. Teaching-research joint appointments were the first step in an integrated program, and in more recent years most extension programs have been placed under the administration of the department head and thus better coordination has been achieved.

Before land-grant universities fully developed their potential in a coordinated way, they too had to evolve. At one time experiment station directors and extension service directors reported directly to the president. Department heads reported to the dean-director who had no responsibility for extension. With the appointment of administrative heads of the college of agriculture, and heads of departments with responsibilities in the three areas, a better system was developed. Research receives inputs from extension

and extension has a better program to extend. As extension has upgraded its personnel, there has been an increase in the joint appointments of research-extension workers. In many instances this has proven to be very productive, but it is one that requires close supervision. It does permit such individuals to be members of the graduate faculty and to supervise graduate students, at least at the mater's degree level. It has also moved some of the adaptive research responsibilities from the researcher to the extension specialist, thus strengthening the efficiency of both. Not all institutions have gone this far in their coordinated efforts, but the trend is in this direction.

The effective extension of ARS production technology is through the state extension programs. The ARS utilization research is transferred directly to the industry. ARS does devote much effort to technology transfer action and regulatory agencies, the industry, producers and consumers through publications and personal contacts.

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Background Paper No. 2

Agricultural Extension Policy: Its Evolution and Current Issues

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AGRICULTURAL EXTENSION POLICY:
ITS EVOLUTION AND CURRENT ISSUES

Introduction

Agriculture in the United States has developed into a highly efficient industry during the past 80 years. Much of this efficiency can be attributed to the system that Americans have devised for developing and transferring new technology to agriculture. Technology development is a major responsibility of the U. S. Department of Agriculture and the nation's land-grant universities, and they are often aided in this task by industry. Technology transfer is the primary responsibility of the Agricultural Extension Service or the Cooperative Extension Service as it is generally known today.

Overview of the Agricultural Extension Service

The Cooperative Extension Service is a unique, complex, American educational institution. Extension employees are located in all states and territories. These employees are distributed in pyramid fashion. At the apex of the pyramid are the employees in the Extension Service of the U. S. Department of Agriculture (ES-USDA). About 100 strong, they represent the federal partner in Extension education, and they constitute about 1 percent of the total Extension staff. The state partners are found at the nation's fifty 1862 land-grant universities, the sixteen

1890 land-grant universities, and at Tuskegee Institute. About one-third of all Extension workers are employed at the state level. The remaining two-thirds of the staff is distributed among most of the nation's 3,150 counties. Providing a broad base for the pyramid are the 3 to 4 million Extension volunteers who help the paid professional staff plan and deliver Extension programs. These are such groups as volunteer 4-H leaders and Extension Homemakers.

Legal basis for Extension

Here is a summary of the basic legislation undergirding the Cooperative Extension Service and related institutions:

Morrill Act, 1862, which created the U. S. Department of Agriculture and authorized the land-grant college system. The land-grant college system is significant because it placed instruction in agriculture and home economics in American higher education.

Hatch Act, 1887, which created state agricultural experiment stations within land-grant colleges to provide a scientific base for agriculture.

Second Morrill Act, 1890, which authorized a land-grant college in 16 southern states for black citizens.

Smith-Lever Act, 1914, which authorized the Cooperative Extension Service. This act enabled land-grant colleges to provide "instruction and practical demonstrations in agriculture and home economics and subjects relating thereto to persons

not attending or residing in said college..."

Historical Turning Points

Many issues pertaining to the Cooperative Extension Service have arisen during the past 70 years which have required both legislative and administrative response. Only the national issues will be highlighted here. It should be noted, however, that state and local issues have influenced the organization too.

The Smith-Lever Act provided $10,000 per state for Extension work, plus a formula for distributing the remainder of the federal funds to the states on the basis of rural population. This method of funding continued until 1923.

Extension responded brilliantly to national agricultural needs during the World War I and to local emergencies. These responses led to the passage of the Capper-Ketchum Act in 1928, which provided for a greatly expanded Extension Service with $1.5 million in additional federal funds. The Capper-Ketchum Act also required one-third of the added funds to be matched within states. In subsequent years full matching was required; however, the formula was still based on rural population. The state partners responded as positively as Congress to the early successes of Extension. They provided their share of matching funds without difficulty.

The Great Depression came as a powerful blow to many Americans, including farmers. As pointed out by Jenkins, Extension workers

dropped most of their other duties with the beginning of the Agricultural Adjustment Administration (AAA) in 1933. For the next six years they generally followed federal government directives. Extension helped to dispense information on the Soil Conservation Service, the Tennessee Valley Authority, the Farmer Security Administration, and the Farm Credit Administration. Extension also accommodated itself structurally to local citizen advisory committees, which it had learned to organize as a result of its AAA activities. These committees aided home demonstration and 4-H agents as they performed services to help economically depressed citizens.

Such responses to the issues of the time resulted in the passage of the Bankhead-Jones Act in 1935. This act provided $8 million in federal funding in 1936 and an additional $1 million for each of the next four years. In a formula change, $980,000 was distributed equally among states and the remainder, for the first time, was based on farm population rather than rural population.

By the late 1930s Farm Bureau dominance was giving way to broader citizen direction. The economic crisis provided leeway in programing.

With the coming of World War II the national consciousness shifted from economic depression to all-out war commitment. Maximum production of food and fiber was the objective. Again Extension adjusted to the needs of the times, according to Jenkins. Congress responded with funds for World War II emergency programs.

While increased agricultural production received Extension's major emphasis, county agents also served on local war boards and organized the rural and urban citizenry for all kinds of war related programs. Thus, the public was further conditioned to accept as appropriate Extension activity outside the narrow confines of agriculture and home economics.

Another important response to the issues of the time occurred in 1945 with the passage of the Bankhead-Flannagan Act. This act paved the way for the further expansion of Extension work. For the first time a portion (2%) of the federal appropriation was earmarked for federal administration. Another 4% was set aside for the Secretary of Agriculture to use as a special needs allocation. The remaining 94% was distributed to the states on the basis of farm population.

Congress amended the Smith-Lever Act in 1953 by consolidating nine existing acts. The revised formula governing the distribution of federal funds provided that subsequent increases be allocated 4% to special needs. Of the remaining 96%, 48% was to be based on rural population and 48% on farm population. The funds were subject to matching by the states. Section 3(d) was added to provide appropriations for the federal staff in USDA.

A Smith-Lever amendment in 1955 set aside special funds outside the formula for the first time. These funds were to be used for the benefit of disadvantaged farmers and were awarded on on the basis of proposals received from states. It was during

this period that massive demographic shifts and revolutionary technological developments were taking place.

Jenkins quotes the federal extension director, who in a 1958 appearance before the House Subcommittee on Appropriations, had this to say:

> "One of the most difficult problems farmers are facing today are the adjustments in agriculture. There was never a time when extension workers have been so pressed to help farm families make these adjustments. Farmers are trying to keep abreast of the tremendous expansion in agricultural technology, mechanization and the rapidly changing economic and rural social scene."

In 1961 more special 3(d) appropriations were made available for resource and community development. Over a 15-year period special 3(d) programs included farm safety, urban gardening, pest management, pesticide impact assessment, energy demonstrations, and non-point source pollution.

The Smith-Lever Amendment in 1962 froze the distribution of current federal funds to each state. Subsequent increases were to be 4% for the federal office; 20% of the remainder was to be allocated in equal proportions to all states, 40% was to be allocated to states on the basis of farm population and 40% on the basis of rural population. The formula remains essentially the same in 1984.

In 1965 section 3(d) was used to provide pesticide chemical programs in Appalachia.

During the 1950s and 1960s, Extension programs were broadened to meet issues of the time. Agriculture became more comprehensive than farming alone. Many opportunities became available for

young people in distribution, processing, transportation, merchandizing and utilization of farm products. As a result, 4-H programs were broadened. Rural residents who migrated to the city created a demand for home economics programs in urban areas.

The Civil Rights Movement of the 1960s resulted in massive federal intervention in state and local affairs to address social and economic injustices. Extension was already involved in social action work in its experimental FES-financed and state directed rural development programs. By 1960 rural development programs were operating in 262 low income rural counties.

Jenkins states that Secretary of Agriculture Benson in 1959 defined the educational function of Extension in rural development this way:

> "In its role as educational leader, extension assists people in identifying resources that will help solve problems, arranges situations which bring problems and resources together and furnishes administrative services to the county and state committees"

This clearly identified Extension's broadening and stimulating social action work. It brought on new efforts in leadership training. New audiences were being served and consulted. Jenkins adds,

> "As in past eras the cooperative structure served extension well, representing it to the outside world while helping it to adjust temperately to shifting economic, social, and political conditions."

A cordial and supportive relationship with both the executive and legislative branches of the federal government was being maintained. A continuous national dialogue within Extension

took place. The FES director participated in meetings of the Extension Committee on Policy (ECOP).

A document entitled the "Scope Report", which was prepared in 1958, spoke to social and economic change and included a comprehensive list of clientele types.

During the 1960s Congress began the heavy use of grants-in-aid financing. This allowed for more rigorous central control and accountability than did formula funding. The Expanded Food and Nutrition Education Program (EFNEP) was established in 1969 under section 3(d) and was expanded subsequently from $10 million in 1969 to $60.5 million by 1975. The funds were allocated to the states on the basis of an administratively determined formula based primarily on the number of families in proverty in each state. Funds were used to employ program aides who were trained by Extension home economists to teach families to improve their diets through education. Many states felt this work was federally imposed and refused to support it. However, in other states it has proved to be a very successful.

Jenkins concludes that "the Cooperative structure seems to be accommodating in more indirect ways the social action interest while also maintaining its traditional middle class clientele."

In 1968, for instance, "A People and a Spirit", a report of the joint USDA-NASULGC Extension study committee, updated the "Scope Report" of a decade earlier by acknowledging and supporting the importance of the Great Society commitment to work on social and economic problems, particularly as it advocated

better Extension worker preparation.

The passage of the Federal Rural Development Act, known as Title V, occurred in 1972. This act authorized expanded work in rural communities in non-agricultural as well as agricultural programs. Funds were distributed 4% for federal administration, 19% for multi-state work, 20% equally divided among states and 33% according to rural farm populations. In 1981 these funds were transferred into Smith-Lever formula appropriations. The appropriations act of 1972 also earmarked funds for 1890 land-grant universities.

Congress in 1973 earmarked funds for 4-H work in urban areas and for rural community development. Such funding continued to expand the ever broadening role of Extension.

The Farmer to Consumer Direct Marketing Act of 1976 funded direct marketing proposals from states.

The Food and Agriculture Act of 1977 refined the Title V formula of 1972 to 4% for federal administration, 19% for farm research programs and 77% for small farm Extension programs. It also provided appropriations for the 1890 land-grant universities and Tuskegee Institute, an amount not less than 4% of the amount appropriated under the Smith-Lever Act. Such funds brought the 1890 institutions more and more into a direct Extension operation previously conducted jointly and cooperatively with the 1862 institutions.

The Food and Agricultural Act of 1977 prompted the appointment of a Director of Science and Education in USDA, the National

Research and Extension Users Advisory Board and the Joint Council on Food and Agricultural Sciences. This act provided that ES-USDA become part of SEA and thereby it lost its agency status. This was a great structural change for Extension and it proved to be unmanageable and cumbersome.

The Renewable Resources Extension Act of 1978 authorized funding for forestry and other renewable national resources. Two million dollars were appropriated in FY 1982 for this purpose for the first time. Extension's role was again broadened.

The Food and Agriculture Act of 1981 increased the 1890 university funding to not less than 5.5% of the total Smith-Lever appropriations in 1982 and to not less than 6% in 1983 through 1985. The Civil Rights Movement created the atmosphere for such legislation. However, funds going directly to the 1890 institutions have brought many adjustments as administrators sought to make the best use of funds and work out new relationships between 1862 and 1890 institutions.

The Food and Agriculture Act of 1981 provided for an assistant secretary of agriculture for science and education. Extension was restored to agency status in the U. S. Department of Agriculture. This enabled Extension to again carry out its important mission in the excellent manner it had before being swallowed up by the USDA bureaucracy in the SEA arrangement.

Clegg points out that the National Extension Advisory Council (NEAC) was formed in this period. The council resulted from the efforts of the directors of Extension and lay leaders. The

Council gives Extension a greater voice in deliberations at the national level regarding appropriations and the very important part Extension plays in the transfer of technology from research laboratories to users.

The Council for Agricultural Research, Extension and Teaching (CARET) was organized for lobbying purposes. The USDA/NASULGC report "Extension in the 80's" was published in 1983. This report is a summary of the findings of a special joint study committee appointed by the Secretary of Agriculture and the president of the NASULGC. The committee's charge was to review and restate the roles and responsibilities of each of the partners in Cooperative Extension and to produce a document that would serve as a guide for the future, mission, scope, priorities, and policies of the Cooperative Extension Service.

GOALS OF AGRICULTURAL EXTENSION POLICY

The basic mission of the Agricultural Extension Service, or Cooperative Extension Service as it is usually called, is to disseminate and encourage the application of research-generated knowledge and leadership techniques to individuals, families and communities. Extension in the '80s lists six program areas in which Extension has responsibility:

The agricultural system;

Natural and environmental resources;

Community and small business development;

Home economics and family living;

4-H/youth education and development; and

International concerns.

Between 40 and 50% of the total resources available to Extension are used in support of the organization's agricultural component, which is the primary focus of this paper. The other components will not be covered unless it seems important to point out how they may impinge on the effectiveness of the agricultural component. The first goal of the agricultural component through the early years was to produce a safe and economical supply of food and fiber for the American people. For many decades now this goal has been expanded to supply food and fiber for people of other lands. This was certainly true during the two world wars when American farmers were called upon to feed much of the free world. They have since been called upon to provide relief for the needy around the world, off-set trade deficits and serve as a model for countries trying to build their agricultural economy.

A second goal of the agrciultural component has been to improve the welfare of rural citizens. While increased efficiencies have resulted in fewer farmers, Extension has helped to give all farm families more of an even chance. This is because Extension tries to apprise all farmers, big and little, of new technology. The 4-H program as related to agricultural production has been very effective in improving the life of rural citizens.

A third goal of the agricultural component has been to protect the nation's natural resources. This was a major goal during the 1930s when Extension took a leadership position in soil conservation and in the formation of the Soil Conservation Service. This goal re-emerged in the 1970s with the nation's commitment to environmental quality. Along with their continuing interest in soil protection, Extension workers are conducting major programs to enhance the quality of water leaving farm and forest land.

The above described goals all related to agriculture, which as pointed out earlier, account for 40-50% of Extension resources with the other five areas of responsibility listed on pages 11 and 12 accounting for the remainder. The historical description earlier in this paper presents dramatically the scope of Extension's growth. Some growth has been by design, especially in 4-H and home economics, but many times historical events have caused Extension to solve problems that have arisen at the time. Thus, it is true that citizens everywhere call on Extension for help when they feel the organization has the expertise to be of value. They even call for help in areas where the expertise may be lacking. Therefore, it becomes very difficult for Extension to define a set of goals and stick with them. Such a broad outreach does affect very materially the resources available to the agricultural function and impinges on the effectiveness of the agricultural programs and the people employed in this area. This is an important issue. However, the strong argument can be made

that in highly urbanized states the most important programs may be non-agricultural. The degree of commitment to each of the above goals will vary from state to state and from county to county within states. This is one of the great beauties of Extension. Its diversity permits experimentation and local adaptation. Also, while the above three national goals have been much in evidence, state and county partners have many additional goals based on local needs.

CLIENTELE FOR THE SYSTEM

The Smith-Lever Act deals with clientele only indirectly. The act says, in essence, that Extension is to diffuse practical information on subjects related to agriculture and home economics through such means as field demonstrations and publications to people who are not enrolled in land grant universities.

The early clientele for Extension was drawn almost entirely from farm families. Included was the farmer himself, the farm wife through home demonstration programs, and farm youth through 4-H clubs.

The clientele has broadened considerably. Farm families still get high priority in Extension educational programs. But the clientele today consists of almost any citizen who could benefit from the research-generated knowledge available to Extension workers.

Key clientele groups, in addition to farmers, would include agribusinessmen; residents of small towns and rural areas; urban users of horticultural, home economics and 4-H information; and the public at large.

The agribusiness concept, which recognizes the importance of the farm supplier and processor as well as the producer in the total agricultural industry, prompted Extension to begin giving higher priority to agribusinessmen in the 1950s. Rural development responsibilities, which were added at about the same time, caused Extension to begin organizing broad educational programs for small town and rural non-farm residents. Suburban livin patterns, featuring individual homes on landscaped lots, prompted a vast demand for educational programs in urban horticulture. Also, the decreasing numbers of people actually engaged in production agriculture prompted the need for better public relations between farm and non-farm people. Extension workers have been asked to assist in this task, thus causing them to regard urban citizens as an important clientele group also.

Home economics programs expanded beyond the farm too as it became evident that rural and urban families shared many educational needs. Among these were foods and nutrition, child care, sewing, housing and house furnishings, family life and care of the aging. The Expanded Food and Nutritional Educational Program (EFNEP) was directed at families of the greatest need regardless of place of residence.

The 4-H program, likewise, now encompasses more than farm youth. This is because of the validity of the "learn by doing" method of teaching 4-H skills and the personal growth stimulated by participation in the program.

Clientele Focus

The question might well be asked, does Extension try to serve too broad a range of clientele with the available resources? The obvious answer is "yes." Once the answer "yes" is decided, the next question is how does one limit the clientele? The historical description provided earlier offers strong evidence that Extension has been called on again and again to use its expertise of planning, organizing and programming with clientele from all walks of life to help solve critical problems. Pressure at the national level has often caused Extension to stray from its purpose and goals. EFNEP is a prime example. Another example was the Rural Development Act. In each instant the national leadership said to Extension, these are new clientele, work with them.

Thus, the dilemma. Although records show that 40 to 50% of Extension funds are used for agricultural programs, the figures are misleading. Personal experience gained over 16 years as director of a state extension service indicates that other programs with widely ranging clientele do impinge on the time that should

be spent with farmers and agribusiness-related activities. This does not suggest in anyway that work with the other clientele groups is not useful and helpful to many citizens.

ROLES OF DIFFERENT INSTITUTIONS IN THE SYSTEM

Federal Role

The Extension Service of the USDA (ES-USDA) represents the federal partnership and provides national leadership in arriving at national objectives and priorities. It performs many administrative, leadership, coordinative and accountability functions. It provides program information to the state partners and the public. I essence, Extension is the educational arm of USDA.

The federal role has changed very substantially over time. For many years a substantial number of specialists with expertise in several disciplines were employed as national leaders. Such people gave leadership to programs at the national level and worked closely with specialists in the states. In recent years a great reduction in the size of the specialist staff has taken place and only a few remain. The reasons for such a reduction are twofold. The first is budget restrictions. Such restrictions have continually reduced staff at the federal level. The second reason is the impossibility of anyone in such a position to remain on the cutting edge of new knowledge without close access to the latest research, such as an individual would have at a land grant university. To expect someone at the national

level to maintain expertise in the rapidly changing technology of today's agriculture seems quite impossible. Perhaps limited exchanges of state and national personnel in a given discipline would be helpful.

The USDA needs to insure that Federal Extension Service is used to disseminate information to the states from other agencies of an educational nature only. The trend has been in the other direction, and it will take a strong position by the Secretary of Agriculture to reverse this. Other agencies must be willing to support increased funds for Extension as their need for Extension assistance increases.

1862 Land-Grant University Role

Land-grant universities provide most ofthe knowledge base from which state Extension services operate. They coordinate Extension programs in their respective states. This means they initiate, implement and evaluate the programs in each state. They work with both the federal and local (county) partners in carrying out this responsiblity, while maintaining the degree of automony that Americans expect of their universities. They also work with state and county governments in securing additional funding for Extension work.

1890 Land-Grant University Role

The Second Morrill Act of 1890 established a land-grant university in 16 southern states for black citizens. The Extension programs

offered by these institutions were for many years under the direction of 1862 land-grant institutions, through which the funds were channeled. The Food and Agriculture Act of 1977 authorized direct federal appropriations to the 1890 land-grant universities and Tuskegee Institute. This has enabled these institutions to take the leadership in developing certain programs. So far, these programs have centered around disadvantaged citizens. Included are programs for small farmers and for intercity homemakers and youth. These programs are coordinated with the 1862 land-grant institutions. Such coordination is carried out differently in different states. The plan of work submitted to the Federal Extension Service from the states must carry the signatures of the directors of Extension from both the 1862 and 1890 institutions. Joint committees and program planning efforts are used in many states from time to time.

The real issue that seems to be developing centers around the relationship of 1890 and 1862 personnel at the county level. Will they be housed together? Will their programs be coordinated? Will they be separate? This is an emerging concern for directors of Extension and citizens today.

PRIVATE SECTOR INTERELATIONSHIPS

Private sector education and promotion activities have evolved with time with public sector research within the land-grant university system. This relationship is not as close as that

between public sector research and Extension.

In fact, in the early years there were no inputs from industry. The relationships between private sector education and promotion activities and public sector research that have now developed can be explained by several factors. The chief factor is the commercial interest that private companies have in new research. New research technology can create new business opportunities or it can outdate goods and services currently being offered by a company. Therefore, it is in the interest of agribusiness firms to stay abreast of public sector research and to encourage farmers to adopt those new practices which are in that company's best interest.

Some companies support, at least in part, public sector research. This gives them an additional incentive to follow the research to ensure the wise expenditure of their funds. Also, many representatives of the private sector share a common background with public sector research and Extension workers. They often graduate from the same university, belong to the same professional associations, and jointly attend educational events at which research information is shared.

While private companies are helping to educate farmers about new technology, something Extension has traditionally done, they are not likely to replace Extension in this role. Nor do they want to. Extension is in a better position to maintain a close working relationship with the total research program. In fact, private companies are usually interested in a relatively

small segment of research. Their interests are concentrated in the crop and animal production areas, especially at the applied end of the research spectrum. Nor are private companies particularly interested in research that does not offer the opportunity for the sale of services or products.

Usually private companies want Extension to remain in the picture because of the tremendous creditability the agency possesses They know that Extension can legitimize new technology in a way that is difficult for them. Also, they know that Extension has a widespread delivery system through which information can be disseminated rapidly if necessary.

It should be noted that the relationship between Extension and the private sector is often an evolutionary process. Extension will introduce new technology from the research laboratories through its educational programs, such as result demonstrations, product testing and the initiation of new crops in an area, and provide some of the initial service work needed to make the technology a success. The service role will then be turned over to the private sector as rapidly as possible, enabling Extension to concentrate on educational programs. Examples are artificial insemination programs for dairymen and nematode assay programs for crop producers. The late Dr. Enos J. Perry, extension professor emeritus at Rutgers University, brought the technology for artificial insemination to the United States from Europe, where it had been developed by research institutions. Dr. Perry initiated an Extension educational program which eventually

resulted in artificial insemination becoming established as a common practice on dairy farms in the United States. In the early years of this program, Extension dairy specialists did the artificial breeding and taught the technique to county agents. Now artificial insemination technicians, many trained by Extension, work for commercial companies or cooperatives, and Extension spends its time conducting educational programs aimed at sire selection and improved genetics.

Private sector involvement in education and promotion has enhanced the need for the unbiased information available from Extension. Private firms, quite understandably, seek to highlight favorable information about their products. It should be pointed out, however, that private firms have made a significant contribution to Extension education. They have provided products for on-farm testing by Extension, hosted Extension educational events, and provided recognition for superior Extension performance. These contributions have enabled Extension to multiply its resources and deliver its message with greater impact. Clientele are often impressed when commercial companies are willing to make a contribution to Extension's effort. Also, an association with Extension and its objectivity might temper claims made by private vendors.

Extension should seek even more private sector cooperation provided that adequate steps are always taken to maintain the intregity of Extension programs. The first safeguard is to make sure that Extension always has a viable educational program for which it is seeking support. It should never structure programs

for the sole purpose of garnering private money or weakening on-going programs in the hope of getting private money elsewhere. Extension must develop its program before seeking private sector support. Second, Extension should seek private funds broadly and not from just a few selected individuals or companies. For example, it is generally preferable to include products from many chemical companies in an on-farm test instead of products from just one or two companies. Likewise, it is generally better to seek funds from broad clientele groups, such as the wheat growers association.

Continuing interaction with commodity groups is needed at the national level to identify problem areas, determine program emphasis and secure resources.

HOW DOES EXTENSION INTERFACE WITH RESEARCH?

Extension interfaces with research differently at the state and federal levels. The manner in which this interfacing takes place has changed over time and differs among institutions.

There is less interfacing of Extension and research at the federal level than in most states. Extension at the federal level has a small staff and these staff members are usually housed apart from USDA researchers. Joint appointments and joint committees encourage close ties between Extension and research, but such arrangements are minor at the federal level. Placing all science and education in the USDA under one assistant

secretary should help to strengthen research-Extension relations at the federal level.

When federal researchers are stationed at the land-grant institutions, they generally enjoy the same ties with Extension as state researchers. The same is usually true for federal researchers stationed at branch research stations around the country.

The amount of interfacing between Extension and research that occurs at the state level usually depends on two factors: the physical arrangements made for staff members and the priority that administrators place upon Extension. Placing Extension and research workers in the same department, where daily interplay occurs, helps to increase interfacing. So do joint appointments, and joint committees and assignments. When administrators demonstrate that they place high priority on Extension, they also encourage a closer working relationship between the Extension and research staffs. Giving research and Extension workers the same fringe benefits and placing Extension specialists on the graduate faculty can also strengthen relationships. Commodity overviews, which bring research and Extension workers together with farmers can also strengthen bonds between the groups.

The increased complexity of research highlights very materially the need for ever closer interaction between research and Extension. One of the big advantages of a close relationship is the feedback from the field that the Extension worker can provide his research counterpart.

ADDITIONAL ISSUES RELATED TO THE COOPERATIVE EXTENSION SERVICE

Some major issues facing Extension have been included in pevious sections of this paper. However, there are other issues that need to be appraised as we look at present policy and its effects on Twentieth Century agriculture.

Dividing Line Between Research and Extension

The cost of doing research has escalated at a faster pace than the dollars made available for research. The dollars that are available have been directed largely toward basic research. This has left a void at times in "adaptive" type research or the testing that must occur before new technology is suitable for farm use. Extension has attempted to fill this void by getting more extensively involved in scientifically validated, replicated tests at the farm level. These tests are more sophisticated versions of traditional on-farm extension demonstrations. **The dividing line between what is the responsibility of research and Extension has changed without the necessary funds for support.** Extension must continue to fine-tune research before the results can be recommended to farmers. Likewise, the private sector will participate in this fine tuning. New technology is often so complex and is influenced by so many variables that it must be adapted to different farming systems and environments. Furthermore, Extension is capable of filling this role. Most new Extension specialists have Ph. D. degrees and are trained in research

methodology. By getting them involved in on-farm testing, they have an opportunity to evaluate new technology under field conditions before it is ready for possible farmer use. On the other hand, time spent in gathering information in this manner can reduce the time spent on educational delivery programs. Thus, the Extension specialist may be caught in the position of trying to serve two masters, and serving neither particularly well.

Size of Farm Served by Extension

Another issue is the size of farms served by Extension. Much Extension information is "non-size" specific and can be used by farmers of all sizes. However, the medium to large commercial farmer has been Extension's most consistent client. On the other hand, some programs have been directed specifically at small and part-time farmers. One example is the Farm Opportunities Program conducted by the 1890 land-grant universities.

Extension should continue to work with farmers of all sizes. About 20% of U. S. farms produce about 80% of the nation's food and fiber. The remaining 80% produce only about 20% of the food and fiber. The big question for Extension is how many resources should be allocated to the 20% and how many to the 80%.

Extension must work with large farmers because the nation's food supply rests largely in their hands. They also help make possible the Extension organization, which in turn can help all farmers -- big and small. Extension helps large farmers in several ways. It provides information about new technology,

often directly from specialists. It can help large farmers indirectly by helping small farmers. Insects and diseases do not respect property lines. If not controlled on small farms they can menace large farms too. The recent outbreaks of Avian Flu is an example. Extension helps both large and small farmers by speaking up for the totality of agriculture, and by helping all segments of the industry see the "big picture"

Small and part-time farmers, on the other hand, need Extension assistance because of economic and social concerns. They do produce part of the nation's food supply. They purchase inputs and sell products that are of value to the agribusiness community, and they contribute to the tax base. Furthermore, resources used with small and part-time farmers can be justified on the basis of Extension's responsiblity for helping people to improve their quality of life. It is one of the most efficient forms of income assistance the government offers. A good Extension worker is more than a source of subject matter knowledge. He or she is also a good teacher and counselor. They are sensitive to the needs of people and inspire confidence in those whom they serve.

The public needs to understand that agricultural policies have been oriented essentially towards a dependable supply of quality food. Some of these policies appear to favor large farmers at the expense of small farmers. Extension has an educational role to play in policy setting but little control. Contrary to some industries, the introduction of new technology in agricultur

benefits consumers in a relatively short period of time, although early adopters get substantial benefits.

Extension also faces the constant challenge of keeping its delivery system geared to the needs of clientele. In some cases, the traditional dichotomy of agent-specialist no longer applies. The level of expertise assigned to a particular area must be governed by the needs of the clientele and the efficient use of resources. The goal is to have a pro-active educational program rather than a reactive one.

Impact of Technology on County Agent

Increasingly complex technology has affected the role of the county agent and the specialist. It has caused an even greater degree of specialization on the specialist staff. It has caused some agents to place more emphasis on planning and implementing educational programs rather than trying to stay abreast of subject matter developments. The county extension office has become a place through which clientele can get reliable help, even though that office may not have all the information immediately at hand. It has caused more and more farmers to go directly to specialists.

Extension must employ the best educated people possible and make sure they have ample opportunities for continued training. This means an increased emphasis on employing people with advanced degrees in specialized areas of agriculture. It also means a well planned and continuous professional improvement program,

which can be time consuming and costly.

Extension credibility is closely tied to the acquisition of new knowledge by its staff. This knowledge must not only be about agricultural technology but also about ways of diffusing it quickly to the user and of finding out what problems farmers are willing to consider. **Many Extension agents are more successful in keeping up-to-date with new research than in getting it transferred to clients.** R. J. Hildreth, executive secretary of the Farm Foundation, points out that

> "the extension professional field worker or specialist plays a somewhat different role than the other professionals with whom he works. Although he is an educator, he operates in an informal, noncertified way, quite different from the classroom teacher. I would say that he or she must be an interpreter."

An option is to provide agents with as much technical support as possible. This may be in the form of area subject matter specialists as well as on-campus specialists. More specialization in assignments at the county level is needed even though it means working across county lines. Another option is to use new delivery technology, such as Teletip and computers. Still another option is to work for higher salaries. This will encourage better trained people to remain with Extension.

The county extension office is serving a broader role as it attempts to meet the needs of commercial agriculture. The county office will continue to provide technological information for commercial agriculture. But one of the most valuable roles the county office serves for commercial agriculture is that

of a contact point. The local staff keeps abreast of the outside expertise that is available for commercial agriculture and then knows how to tap that expertise when needed. Thus, the county staff functions as organizers and facilitators as well as a direct source of technological information.

County staffs should know what resources are available at the land-grant university and how to bring them to bear on local problems. They should possess a certain amount of subject matter training, depending on the particular county. They should be supported with an adequate staff of specialists and area agents. Also, it should be pointed out that modern agriculture faces more than just production problems. Farmers need educational assistance on environmental problems, public policy issues and marketing questions as well. Some of this assistance can best be provided by specialists, contacted through the county office. But specialists should keep agents involved and informed when they work directly with large commercial farms and agribusiness firms. Agents should also be aggressive in organizing training opportunities for consultants, bankers, servicemen and other representatives from the private sector who serve farmers. These people should be viewed as resources that can magnify the Extension outreach rather than as competitors. Finally, the county extension office should be constantly assessing the problems of commercial agriculture and relaying them to the research staff. They should also report on the results that commercial farmers are obtaining with new technology.

Cost of New Delivery Technology

Delivery technology is costly. A state extension service can easily spend from 5 to 10% of its operating budget on computers and electronic technology. One state recently spent $420,000 to equip 70% of its counties with microcomputers, and this is only part of the cost. Software must be developed, personnel must be trained, and before long existing computers must be replaced by newer models. Statewide telecommunication systems will expand Extension's capacity to provide clients with fast, accurate information needed for making informed decisions. Yet, such systems, linked possibly by satellites, will be expensive. Whil these new delivery systems will permit Extension to do more things more quickly, there is no indication that they will replace, entirely, any of the older delivery systems.

Extension's only choice is to invest in new technology. Farmers have been investing in new technology for years. Extension can do no less. In fact, the efficiency gains that are to be made in the near future are likely to come through improved technology rather than through additional personnel. The problem is securing funds to pay for it. Public funding will be essential for most states. Some private grants may be available for innovative new delivery systems. Also, Extension may have to recover part of the cost through user fees. For example, a charge for computer

software packages would be just as appropriate as a charge for more expensive publications. The need for non-salary items must be established just as firmly in the minds of legislators, congressmen and county commissioners as the need for non-salary support in research and teaching. It is part of the cost of doing business today.

Economic-Biological Interaction

The lack of economic-biological interaction can have a devastating impact for farmers who adopt new technology without evaluating the costs and returns of that technology. This is why Extension has put a lot of emphasis on the farm and home management approach to education since the 1950s. This approach emphasizes not only new agricultural technology but includes a total study of farm assets and emphasizes the management of resources.

Economics has become even more of a factor in decision making in recent years. This is why Extension must employ more agents with a stronger background in the subject. Emphasis must be on the discipline of economics and its application rather than straight theory, and many departments are not structured to teach courses this way. In-service training in economics will help, but it is not sufficient alone. Also, Extension must promote a systems approach to its educational programs, which incorporates economics into the total package. The use of commodity coordinating committees, which include economists, helps to ensure this approach.

Establishing Extension Priorities

The setting of Extension priorities when resources are limited is a critical point. Extension priorities usually result from a synthesis of national, state and local needs. Local needs flow upward and national needs are communicated downward. Formula federal funds allocated under the Smith-Lever Act give states great freedom in setting priorities. The state extension office with input from subject matter departments at the land-grant universities usually sets broad parameters for Extension work in that state. These parameters may be established with the aid of citizen advisors. Specific Extension priorities are usually established at the county level. These priorities are almost always set with the advise and support of citizen advisors. Thus, priorities are usually of a three tier nature - federal, state and county, just as Extension funding.

The present method of establishing priorities would be hard to beat. A number of systems may be used but each in their way is an attempt to maintain a dynamic process. National interests are given due consideration. Guidance from state leaders occurs. Clientele groups make an input. This helps to ensure that local Extension programs stay in tune with the needs of the people which they are designed to serve. It is a dynamic process which has served the nation well.

Continuing Extension in Era of Surplus Production

The question is often asked why should we do Extension work when surplus production already exists? Temporary surpluses of some commodities may exist in the United States, but on a worldwide basis food is in short supply. The problem is one of inadequate distribution and the ability of developing nations to pay for food rather than overproduction. Also, yields can fluctuate widely from year to year because of weather and pests. Therefore, it will never be possible to bring production precisely in line with demand. Also, it should be emphasized that much of Extension's effort is directed toward maintaining the production that already exists. Weather and pestilence will never permit a status quo situation in agriculture.

The wise course is to maintain a dynamic Extension program. New technologies must be delivered if farmers are to protect current supplies of food and fiber and to meet the needs for future increases. Agriculture competes in a world market as do other segments of the economy. The competitive edge of U. S. farmers would soon be lost without new technology. **Research and Extension cannot be turned on and off like a spigot.**

FUTURE DEVELOPMENTS IN EXTENSION POLICY

Clegg points to some new assumptions and directions. Such ideas are drawn mainly from the overall priorities of the Reagan Administration and "Extension in the 80's." The assumptions

on the part of the administration suggest that the American economy will be strengthend when federal spending is brought under control and that state and local governments can play a stronger role in public services. Much more is to be expected from the private sector in strengthening the nation's economy and many more vital services must come through voluntary effort. Such assumptions are being used as a guide by federal managers of the Reagan Administration. **This policy suggests less FES funds and less FES direction.**

Extension is a tested and tried continuing education system. It has made many adjustments both structurally and programatically in its 70 years. It will continue its basic mission as pointed out by Clegg to "disseminate and encourage the application of research generated knowledge and leadership techniques to individuals, families and communities."

Support must be increased if Extension is to fulfill such a mission in the six areas identified in Extension in the 80's. It is very important that broad flexibility be retained by the state and county partners in the priority setting process. Likewise such priority setting should include a much needed leadership ingredient from the national level to reflect national concerns that are important to citizens in each state and county and should be reflected in their state and county programs. Thus programs will be vastly different between states and within states and between counties within each state.

A future development certainly centers around electronic

technology to teach, demanding an ever increasing expertise and dependence on better trained people at all levels. The use of computers and all other forms of emerging electronic technology will be a real challenge to Extension. The private sector relationship will continue to expand and the utilization of private funding sources will increase. Such future development suggests an ever increasing budget. Such increases are not likely to become available through public sources. Therefore, Extension will learn to do more with less through better programming. This requires a careful study of priorities and pay-offs.

In such priority setting it becomes quite clear that if Extension is to remain a viable educational unit for transferring agricultural technology it must make sure its resources committed to agriculture are used for that purpose. The figures now showing 40 to 50% of Extension funds being used for agricultural purposes are misleading as was pointed out in an early section of this paper. There is no question but what Extension must refine to a considerable extent the clientele that are to be included in the system that they plan to serve in the light of budgets that may be declining.

Likewise, as such clientele are defined and priorities are set more resources must be put into training and retraining of personnel than most directors of extension have ever been willing to commit. This is important if any semblance of Extension credibility is to be maintained. This will require not only agricultural technology but also ways of diffusing it quickly to the user.

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Background Paper No. 3

Economic Impact of Agricultural Research and Extension

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ECONOMIC IMPACT OF AGRICULTURAL RESEARCH AND EXTENSION

Fred C. White*

Agricultural research and extension were originally intended to make the family farm more efficient and thus more profitable (Paarlberg). Investments in these activities, however, have had far reaching consequences on factor productivity and use; quantity, quality, and price of agricultural products; farm structure; environmental quality; foreign exchange earnings through the export of agricultural products; and the general level of economic activity. The benefits to society from agricultural research and extension include expanded supplies and lower prices of agricultural products, release of farm labor and other resources from agriculture to other sectors of society, and expanded aggregate economic activity linked directly and indirectly to expanded agricultural production. However, there are increasing concerns that both the beneficial and adverse impacts of research and extension on the environment, farm labor, rural communities, and farm structure be identified and that any adverse consequences be addressed. Only through the identification and measurement of all major consequences of research and extension is it possible to determine whether society's investment in these activities have produced the desired results.

The overall objective of this report is to analyze the impacts of agricultural research and extension. Particular attention will be focused

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on the impact of agricultural research and extension on farm structure.The paper will review previous literature related to the area and develop and apply a theoretical framework to measure the impact of research on supply responsiveness of farms of different sizes. This background will be used to identify and discuss research and extension policy options that might be used to change the future structure of farms in some desired direction.

Impacts of Agricultural Research and Extension on Society's Well-Being

Agricultural research and extension constitute an investment aimed at improving society's well-being by raising returns to factors of production through lowering costs or increasing output, by improving product quality or introducing new products, and by reducing farmers' vulnerability to forces beyond their control (Arndt and Ruttan). This section contains a brief overview of the benefits of agricultural research and extension with a recognition of adverse impacts followed by three subsections containing a more in-depth discussion of some of the more important issues raised in the overview. First, a framework to quantify the benefits will be presented. Secondly, the empirical estimates of benefits will be reviewed. Thirdly, the distributional impacts of agricultural research and extension will be discussed.

In the nation's early history, a large portion of the work force was in agriculture. Rising real wage rates in the nonfarm sector and "labor shortages" during major wars have contributed to the development and adoption of labor saving devices in agricultural production (Ruttan, 1982). As labor efficiency increased in farming due to research and extension activities, labor was released from farming and became available

to produce other goods and services. The resultant mass migration of farm workers to the nonfarm sector provided an impetus to the nation's economic development. While this historical perspective is well documented and widely understood, the current impacts of research and extension warrant further elaboration.

A wide range of activities are encompassed by the broad category of agricultural research and extension, and consequently the benefits from these efforts are far reaching. The most obvious benefit of research and extension is productivity growth and increased supplies of food and fiber. Contributing to this increased supply of products has been research focused on increasing yields and reducing costs at the farm level, reducing costs and/or preventing losses in the farm-to-retail marketing channel, and preservation and/or enhancement of product quality. Research and extension related to production, processing, preservation, transportation, marketing and distribution of food contribute to expanded supplies and lower consumer prices. The quality and safety of foods have also been improved by research and extension activities.

By contributing to increased agricultural output, research and extension have expansionary impacts on other sectors of the economy. Farming is linked directly to input suppliers and agricultural processors; hence an increase in farm production will increase economic activity in the agricultural supply industry and agricultural processing industry. These changes also rebound throughout the general economy because of interlinkages among farming and other sectors.

A further benefit from expanded supplies and lower prices is a positive contribution to the nation's trade balance. A large volume of agricultural exports provides foreign exchange needed to import foreign products.

Research and extension have contributed to the nation's competitive advantage in world markets for agricultural products.

Technology has had favorable effects on the environment in some instances and unfavorable effects in others. New reduced and minimum tillage practices reduce soil and water losses. Research on integrated pest management and pest resistant crop varieties, which has reduced the use of chemicals, has helped reduce the environmental impacts of agricultural production. Expanded agricultural production and advanced technology have adversely affected environmental quality, in some instances, by increasing soil erosion and increasing environmental loadings of soil, pesticides, and plant nutrients in surface and/or subsurface bodies of water. Research and extension activities are underway to reduce such adverse impacts of changing technology on environmental quality. Many research and extension efforts have been aimed at improving environmental quality. As a consequence, numerous environmental problems in pest control, soil and water management, and waste disposal have been solved. However, advanced technology has had mixed effects on the natural environment.

Research and extension have had differential impacts on farms, farm workers, agribusiness, rural communities, and even entire regions depending on their characteristics and the type of technology developed. Some technological innovations, particularly mechanical innovations, have favored and henced fostered larger farms. Other technological innovations that could be applied on farms of any size are often first adopted by larger farms (Paarlberg; Perrin and Winkelman). By being the first to adopt new technologies, larger farms receive greater benefits than those not adopting the technologies which are typically smaller farms.

Consequently, changing technology has contributed to the changing farm structure, characterized by fewer and larger farms. Increased labor productivity associated with new technology has resulted in higher wages for some skilled workers but fewer job opportunities in farming. Adjustment costs for many farmers and farm workers who have been displaced from farming by changing technology have been substantial. Improved technologies have benefited some agribusinesses and rural communities serving those segments of agriculture that benefited from the new technologies. However, declining farm numbers, along with outmigration of farm workers, has adversely affected many agribusiness and rural comunities.

Analytical Framework

While it is recognized that the impacts of agricultural research and extension are multifaceted, the major impacts can be quantified through the analytical framework developed in this section. The model presented links cost curves for individual producers to market supply. Consideration of cost curves for individual producers provides the basis for a discussion of structural implications. Consideration of the economic model of supply and demand provides the basis for a discussion of aggregate effects.

Agricultural research and extension are characterized in this analytical framework by the development and dissemination, respectively, of improved technologies. Adoption of such technologies by producers is assumed to result in lower costs per unit of output and expanded aggregate supplies, as depicted in Figure 1. Figure 1 has two panels: panel a shows cost curves for individual producers and panel b shows market supply and demand curves for an agricultural commodity. Supply shows the quantities that would be offered at alternative prices. Demand, which has both

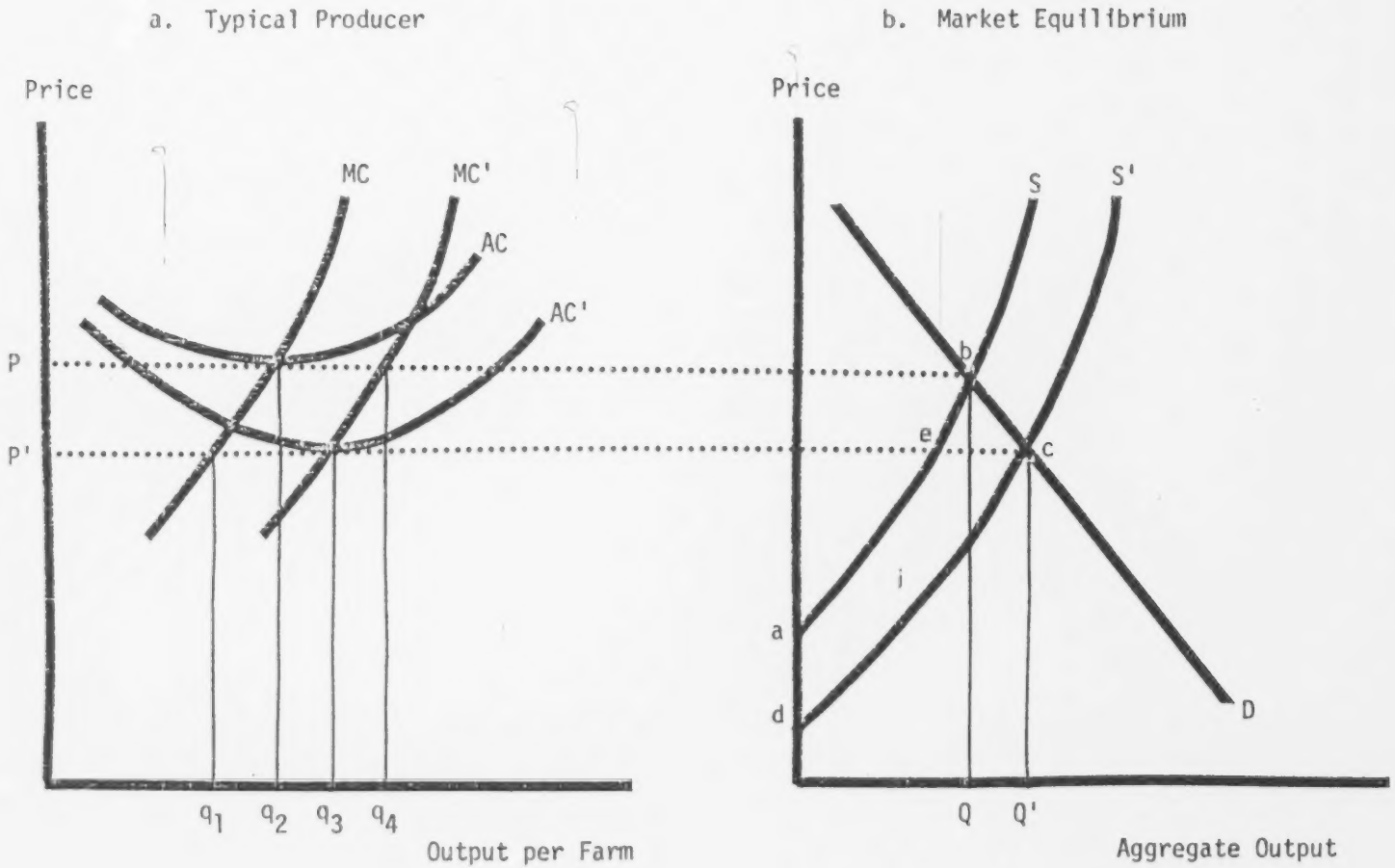

Figure 1. Economic Effects of Research and Extension on Individual Producers and Market Equilibrium

domestic and foreign components, shows the quantities that would be purchased at alternative prices. Given the initial supply (S) and demand (D) conditions, equilibrium price would be P and aggregate quantity traded would be Q.

Initially, the average and marginal cost curves for the typical producer are shown by AC and MC, respectively (Figure 1, panel a). The typical producer maximizes profit by producing that level of output (q_2) which equates marginal cost with output price (P).

After the typical producer adopts the new, superior technology, his average and marginal cost curves are depicted by AC' and MC' (Figure 1, panel a). This producer has an incentive to expand output to q_4 at the initial price P. However, as a large number of farmers expand output in such a fashion the aggregate supply shifts from S to S' (Figure 1, panel b). The result of an expansion in supply would be a lower equilibrium price (P'), ceteris paribus. The producer who had adopted the technology would maximize profits by producing output level q_3, which equates marginal cost MC' with the new equilibrium price P'.

If some of the producers did not adopt the new, superior technology, then their average and marginal costs would continue to be depicted by AC and MC, respectively (Figure 1, panel a). These producers would receive a market price (P') which is below their average cost. It would be economically feasible to these producers to reduce production to q_1 and continue to operate so long as the output price was above the average variable cost. However, in the long run as more factors of production become variable rather than fixed the average variable cost curve would approach the average cost curve. A producer would be expected to cease operating whenever he is unable to cover variable costs.

The differential impact of technological change on the two groups of farmers is to increase output for the group adopting the technology and to reduce output for the group not adopting the technology. Within the group not adopting the technology initially, some would be forced to adopt the technology later, some would continue operating but at a lower level as long as variable costs were covered, and others not covering variable costs would exit the industry. By using superior technology the early adopters would have a competitive advantage over the other producers, resulting in higher profits and an incentive to expand production. Hence the early adopters would tend to expand by buying out those producers which had not adopted the improved technology (Knutson, Penn, and Boehm). The structural implications of this model will be empirically estimated in a later section by examining both the decision to continue to operate and the decision of what level of output to produce for small and large farms producing selected commodities.

One way to measure aggregate benefits from research and extension within this framework is to measure economic surplus, which reflects consumer and producer welfare (Hertford and Schmitz).[1] Since the supply curve is assumed to have shifted outward as a result of increased productivity, the increased economic surplus is the area between the two supply curves but under the demand curve (abcd). Consumers would clearly

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[1]Economic surplus is the sum of producer and consumer surplus which can be defined as follows. Producer surplus, which is a measure of returns above variable costs, is the area between the price line and the supply curve. Consumer surplus, which measures the difference between what consumers are willing to pay and what they actually pay, is the area between the demand curve and the price line. Economic surplus then is the area between the demand and supply curves.

benefit, because they are able to purchase more of the product and at a lower cost. Consumer surplus would increase by the area PbcP'. Producer surplus would change by aecd minus PbeP', with the latter area transferred from producers to consumers as a result of the lower price.

To quantify this model, the information is needed on supply and demand parameters, particularly price elasticities.[2] Also, information is needed on how the supply curve shifts as a result of changes in research and extension (see Lintner and Jarrett). The benefits can then be compared with costs of research and extension in the context of a benefit-cost analysis.

The manner in which gains from agricultural research and extension are distributed between producers and consumers depends on the price elasticities of supply and demand and the rates of growth in supply and demand. If demand is highly elastic and rapidly growing, a large portion of the benefits from research and extension accrue to producers. If demand is inelastic and growing at a slow rate, a large portion of the benefits are passed on to consumers in the form of lower product prices. While the demand elasticities and growth rates vary by commodity, meats and fruits and nuts generally have more elastic domestic demands than vegetables and grains (Brandow; George and King). The aggregate domestic demand in the U.S. is inelastic and slowly growing (Hathaway), which accounts for the

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[2]The price elasticity of demand shows the responsiveness of quantity demanded to changes in price and can be measured as the percentage change in quantity demanded brought about by a one percent change in price. The price elasticity of supply shows the responsiveness of quantity supplied to changes in price and can be measured as the percentage change in quantity supplied brought about by a one percent change in price.

fact that a large portion of the benefits from research and extension have historically accrued to domestic consumers.

The demand curves faced by U.S. producers are a weighted average of domestic and foreign demand curves. The weights for the two have shifted over time for most commodities, changing the aggregate price elasticity when the two price elasticities are not the same. The export market tends to have a more elastic demand than the domestic market, because foreign countries might purchase from any one of several exporting countries. Considering the dramatic increases in U.S. exports of agricultural products, particularly wheat, feed grains, and soybeans since 1970, the foreign elasticity of demand has increased in relative importance and hence carries a greater weight in determining the aggregate elasticity of demand for these commodities. Hence, the overall elasticity of demand for major export products has probably become more elastic over the last 15 years (Bredahl, Meyers, and Collins). A larger share of the benefits from agricultural research and extension activities related to export commodities may now be captured by domestic producers.

The simple analytical framework developed above and presented graphically in Figure 1 can be modified in several ways. The model can be applied to a closed economy or an open economy that takes into account exports and imports (e.g. Schuh). In that case, the demand for exports could be added to domestic demand and the supply of imports could be added to domestic supply. The model can be used to consider the impacts of research and extension while accounting for government price supports and trade policy (Ayer and Schuh). Schmitz and Seckler extended the basic model to account for unemployed labor that had been displaced by technological change.

Output Effects

Placing market valuations on potential outcomes for various program areas, including agricultural research and extension, through benefit-cost analyses facilitates efficient resource allocation. Once the stream of benefits and costs have been identified for each time period, it is possible to calculate a rate of return on investment. As long as the projected rate of return for a particular alternative is above the social rate of return then investment in that alternative would be desirable. Ruttan (1980) has argued that a social rate of return around 20 percent would be appropriate to compare with estimated rates of return on agricultural research (and extension).

Rates of return on public investment in agricultural research typically fall in the 30-60 percent range (Ruttan, 1980). The rate of return estimates for aggregate investment in agricultural research in the United States has generally shown a moderate trend downward through time (Peterson and Fitzharris; Lu and Cline; Davis). An interesting conclusion by Bredahl and Peterson that rates of return estimates were roughly equal for four major commodities--cash grains, poultry, dairy, and livestock--is an indication of efficient allocation of research funds among commodity areas.

On the basis that it is difficult to separate the effects of research from those of extension, some studies have estimated the combined effects of research and extension. Estimates for the rate of return on research and extension combined are of similar magnitudes to the returns on research, ranging from 23.5 percent to 49.7 percent (Table 1). These returns have also shown a moderate downward trend through time.

Since 1970 there have been several studies conducted to separate the effects of agricultural extension on productivity (Table 1). Evenson's

Table 1. Empirical Rate of Return Estimates for Agricultural Research and Extension Investment in the United States

Study	Commodity or Region	Time Period	Internal Rate of Return
			(Percent)
Agricultural Research			
Griliches (1958)	Hybrid Corn	1940-55	36-40
Griliches (1958)	Hybrid Sorghum	1940-57	20
Griliches (1964)	Aggregate	1949-59	35-40
Peterson (1967)	Poultry	1915-60	21-25
Evenson (1968)	Aggregate	1949-59	47
Peterson and Fitzharris (1975)	Aggregate	1937-42	50
		1947-57	51
		1957-62	49
		1967-72	34
Bredahl and Peterson (1976)	Cash Grains	1969	36
	Poultry	1969	37
	Dairy	1969	46
	Livestock	1969	47
Davis (1979)	Aggregate	1949	100
		1954	79
		1959	66
		1964	37
		1969	37
		1974	37
Norton (1980)	Cash Grains	1974	85
	Poultry	1974	46
	Dairy	1974	51
	Livestock	1974	88
Agricultural Research and Extension Combined			
Lu and Cline (1977)	Aggregate	1938-48	30.5
		1949-59	27.5
		1959-69	25.5
		1969-72	23.5
Knutson and Tweeten (1979)	Aggregate	1939-48	49.7
		1949-58	47.4
		1959-68	39.4
		1969-72	35.5
White, Havlicek and Otto (1978)	Aggregate	1929-41	36.5
		1942-57	32.2
		1958-77	27.8
Agricultural Extension			
Huffman (1974, 1977)	Corn Belt	1964	16-110
Huffman (1976)	La., N.C., Okla.	1964	180-460
Evenson (1979)	Aggregate	[illegible]	55
Huffman (1978)	South	1964	200-260

(1979) analysis indicated a 55 percent rate of return on extension and that the marginal rates of return to research and extension were similar. Huffman reported rate of return estimates of over 100 percent for some extension activities.

The high rate of return estimates indicate that agricultural research and extension activities have been very productive. However, in terms of economic efficiency more funds should have been allocated to these areas in order to drive the rate of return on research and extension down to the social rate of return.

Distributional Effects

In addition to affecting the distribution of income among the broad categories of producers and consumers as discussed above, agricultural research and extension has important distributional effects within farming and within rural areas in general. By changing the efficient mix of inputs used in farming, research and extension can cause changes in the distribution of income among productive inputs.

Changes in the relative productivity of land, labor, and capital can influence the share of income attributable to each of these inputs. These changes in productivity can be viewed as shifts in factor demand curves. The interaction of supply and demand will determine levels of factor use and factor returns. Hence supply elasticities are important in determining the income effects due to shifts in factor demands, resulting from research and extension. Land services are quite inelastic in supply, which means that land rental rates and land prices are sensitive to shifts in demand for land services. In contrast, most other farm inputs have more

elastic price elasticities of supply, indicating shifts in factor demand might change input usage with little or no impact on factor prices.

Farm Operators. Results from agricultural research may have varying effects on producers by size categories, by geographical region, and by commodities being produced. Some mechanical innovations have favored large-scale farms on the basis of economic efficiency rather than some physical limitation. A technology which is adopted only in a limited geographical area, particularly biological innovations such as the development of improved crop varieties, can alter comparative advantages among regions. Using new technologies in the production of one commodity may impact on the production and/or utilization of other commodities. For example, an improvement in beef production resulting in lower beef prices might affect pork and poultry consumption and the demand for feed grains.

Whenever economies of size are present there are economic pressures to expand farm size, because larger farms would have lower costs per unit of output than smaller farms. There is considerable controversy over the magnitude of cost savings associated with increasing farm size. Distinguishing between technical economies and pecuniary economies[3] sheds some light on the controversy. There appears to be a significant technical basis for economies of size, i.e. technology has lowered per unit costs by a greater degree on large farms than on small farms (Hall and LeVeen, Jensen). When only technical economies are considered, it appears that

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[3]Technical economies, as a form of cost reduction, arise primarily through reorganization of factors as the indivisibility of factors is overcome when size and output are increased. Pecuniary economies, as a form of cost reduction, arise by purchasing of factors or credit in large scale lots (Heady, 1952).

relatively modest sized farms can achieve a major portion of the possible cost savings associated with size. Costs in highly mechanized crops generally continue to decrease slowly throughout the entire range of surveyed farm sizes; but in vegetable and fruit crops, costs do not appear to decrease substantially after an initial phase of rapid decline (Hall and LeVeen). Miller, Rodewald, and McElroy in a study of economies of size of U.S. field crop farming found that as farm size increases in most field crop regions, per unit costs decline at first, and then are relatively constant. There is some evidence that when pecuniary economies are considered the unit cost curve does not flatten out but continues to decline with larger farm sizes (Knutson, Penn, and Boehm).

Technology affects farmers according to the speed with which new innovations are adopted. The larger, progressive farmers can benefit from a new technology through early adoption. Adoption lags which systematically favor the larger farmers, occur because it is more profitable for large farms than small to invest in acquiring information. There is a concern that in the case of integrated agriculture certain types of information may be only available to those that are a part of the system. In a study of adoption of new crop varieties, Perrin and Winkelman noted that new seed varieties and fertilizer which should help both large and small farms, favored larger farms because the small farms lagged behind in the early stage of adoption.

Farmland Owners. Technological change affects the productivity of land and hence impacts on the demand for farmland and its price. Farmers would therefore be affected according to the amount of farmland owned. An increase in the value marginal product of land will favor owners relative to renters. The distinction between farmland owners and renters is

becoming more important because an increasing proportion of farmland is rented and a larger proportion of farmers rent part of the land they operate (U.S. Department of Agriculture, Agricultural Statistics). Herdt and Cochrane (1966) reported that technological advance with stable or rising prices has benefited farmland owners, not necessarily farm operators. They said that farmers view technological change as reducing cost of production and hence are able to bid up the price of farmland accordingly. Heady (1971) argued that rapid increases in agricultural productivity would lower the value productivity of farmland in the case of low price elasticities of demand for farm products, reducing farm revenue. While the net effect of technological change would be to lower the share of total income attributable to farmland, farmland prices increased during periods in which the government supported prices because of compensatory government programs. With price supports, increased productivity resulted in sizable capital gains to farmland owners (Cochrane, 1965). However, these capital gains must be evaluated in terms of the government programs in effect to support farm prices and not be considered as the sole responsibility of technological change.

Farm Workers. Changes in the proportion of farm income attributable to labor depends on the type of technology. Labor-saving technology reduces the demand for labor. Mechanical technology, which has been developed almost entirely by private sector research, generally can be characterized as labor-saving (Evenson, 1980). Estimated income effects indicate that technological changes have increased the marginal physical productivity of labor used in farming (Wallace and Hoover, 1966). The result is an increase in the demand for labor if farm product prices are unaffected. However, as farm prices adjust downward to expanded output resulting from

technological change, the demand for labor declines because the demand for agricultural products is inelastic (Bauer, 1969).

The differential impact of technological change on certain groups of labor is evident. Workers whose skills complement agricultural innovations have experienced an increase in their marginal productivity and in their real income. However, unskilled workers who do the same work that can be done by mechanical innovations have experienced a decline in the demand for their efforts. Those workers remaining in agriculture have faced prospects of declining real incomes.

The substitution of capital for farm labor can have adverse effects on workers not suited for nonfarm employment because of age, lack of skills or inadequate employment opportunities. This problem has associated with it social costs that include unemployed resources and increased social services for displaced farm workers.

Rural Communities. Technological changes in agriculture have had far reaching effects upon the development of rural America. No attempt has been made to develop technology consistent with any particular pattern of social and economic organization (Bishop). Instead, the development of technology to provide the most efficient production of commodities has been emphasized, and the pattern of social and economic organization has been determined by market forces as producers adjust to that technology. U.S. farmers have increased agricultural productivity largely from the substitution of improved capital inputs for farm labor (Tweeten, 1979). Fewer job opportunities in farming forced many workers to seek employment in the nonfarm sector often outside the rural areas in which they had been living.

Mass migration from U.S. farms over the last half century has been one of the most significant cultural and economic developments experienced in history. The exodus was caused largely by diminished economic opportunities on farms and the lure of increased economic opportunities elsewhere, primarily in urban areas but also in other rural areas. Many of these displaced farm workers found jobs in the nonfarm sector or other expanding farming regions. In such cases society's total economic well-being was generally increased, because the workers earned more income than they had been earning previously. However, many displaced farm workers were unable to secure employment after migrating to other areas, because they lacked appropriate education and skills to fill the available jobs or too few jobs were available. In the cases in which migrants did not find jobs they generally added to the areas' problems associated with unemployment, poverty, congestion, etc.

Many rural communities that had previously served populous farming areas deteriorated as the number of farm owners and farm workers declined. The tendency for people to leave rural areas has affected the viability of many rural commercial enterprises, churches, community services and, in some cases, entire communities. In the Great Plains and Western Corn Belt regions the rural population fell 27 percent since 1940, and in the Coastal Southern Plain the rural population fell by 36 percent (Brown). On the other hand, some rural communities have benefited from technological change. Those areas experiencing rapid growth within agriculture have responded with more agribusiness services and community infrastructure and economic activity.

The type of farm organization appears to have an impact on rural communities. Larger farmers often purchase inputs at larger towns in order

to get specialized services and/or lower costs. Also, larger farmers often find it advantageous to market their products in larger farm service centers. As a follow-up to earlier research, the Community Services Task Force reported that the scale of farming is related to trade center growth and change through its impact on retail trade, public services, social and civic organizations, churches, and local decision-making. These effects are different from, although not completely unrelated to, declining demand for farm labor.

Impact of Research and Extension on the Structure of Agriculture

This section examines the extent to which agricultural research and extension affect farm structure. The structural neutrality issue is described in detail and subdivided into its component parts of research neutrality, dissemination neutrality, and adoption neutrality (Lu, 1984). Then an in-depth analysis of research and extension impacts for selected major commodities is presented.

Structural Neutrality

Structure as related to agriculture is a multifaceted concept. Penn identified the following components of structure (USDA 1979, modified):

Organization of resources into farming units;

Size, management, and operation of those units;

Effects of different types of organizations and techniques on natural resources;

Ease of entry into the food and agricultural industry;

Manner in which the firm procures its inputs and markets its output;

Performance of the food and agricultural industry in providing the quality and quantity of food sought by the consumer;

Degree of freedom to make business decisions, and the degree of risks borne by the operator;

Restrictions on land use;

Manner of asset transfer to succeeding generations.

In the broadest sense, research and extension could affect structure of agriculture by affecting any of these components. Operationally, structure is often focused on the number of farms and the size distribution of farms. The major public concern over research and extension and structure was explicitly brought to public attention by Hightower in 1973. He alleged the research and extension system gave a preference to large farms and geared research toward large scale operations.

In order to examine the effect of research and extension on the number and size of farms an operational definition of structure that accounts for the number and size of farms will be utilized. Penn used the term "family farm structure" referring to a relatively large number of modest-sized farms operated by a family unit (USDA, 1979). Within the context of this operational definition of structure, the agricultural research and extension system would be characterized as structurally neutral if it does not favor farms of a particular size. Alternatively, the agricultural research and extension system would be considered structurally non-neutral if it favors farms of a particular size, contributing to a changing farm structure.

The impact of the agricultural research and extension system on farm structure can best be understood by considering the separate impacts of research, extension, and technological adoption on farm structure. Agricultural research that develops technologies which could be used efficiently by any farm size would be considered structurally neutral. For

simplicity, the term "research neutrality" is used to describe research if it does not favor farms of a particular size. Agricultural extension would be considered structurally neutral if it provided to farms of all sizes information on technology that could be effectively utilized on farms of all sizes. To cover this situation, the term "dissemination neturality" is used to describe extension if it does not favor farms of a particular size. In order for the technological adoption process not to affect farm structure, farmers of all sizes would have to adopt new technologies at a similar rate. The term "adoption neutrality" is used to describe the adoption process if it does not favor farms of a particular size. Hence, the overall issue of structural neutrality can be broken down into its component parts of "research neutrality," "dissemination neutrality," and "adoption neutrality." Although it may be difficult to empirically separate these effects, this separation does appear useful in a conceptual and policy context, because it helps identify where efforts are needed to achieve greater structural neutrality if so desired.

First, consider the concept of "research neutrality," which is related to whether or not emerging technologies favor a particular farm size. There is limited evidence that the type of agricultural research presently being conducted by public institutions is structurally neutral; this is true, at least, at the conceptual level. A task force appointed by the Experiment Station Committee on Organization and Policy (1981) recently assessed the role of agricultural research in bringing about changes in structure, particularly dealing with the concentration of production on larger farms. Results from that study indicate that production research of agriculture experiment stations was not slanted toward large farms. Of all production research, 78 percent of scientific year (SY) effort was judged

to be applicable to all farms, 10 percent primarily useful to small farms, 7 percent primarily useful to moderate-sized farms, and 5 percent primarily useful to large farms. There is, however, some concern over the objectivity of these results, because the data were internally generated.

An examination of emerging technologies gives further insight into the role of agricultural research in changing farm structure. The agricultural research system is presently focusing on a number of biological-chemical technologies that are expected to be on line prior to the year 2000 (Lu). These include enhancement of photosynthetic efficiency; water and fertilizer management; crop pest control strategies; controlled environment or greenhouse agriculture; multiple and intensive cropping; reduced tillage; bio-regulators; new crops; bio-processing; antitranspirants; development of plants to withstand drought and salinity; and twinning. Theoretically, most of these emerging technologies could be applied on various sizes of farms.

While publicly supported research is primarily focused on the biological-chemical technologies, research in private industry is primarily responsible for the major mechanical innovations which favored large farms. The cotton picker and chemical weed controls, for example, contributed to larger operating units in cotton production in the South. Mechanical innovations such as the tomato harvester (see Schmitz and Seckler) have favored large farms by reducing labor requirements and lowering costs per unit on large farms by spreading a given level of investment cost over more units of production. In general, there has been no widespread public recognition of the consequences of such technological developments before the technologies were released and widely adopted.

"Dissemination neutrality" deals with the issue of whether or not dissemination of research results by research and extension personnel is structurally neutral. Research results are released through a wide range of publications, including journal articles, experiment station and extension service publications, and the popular press. These publications would tend to be more accessible to more knowledgable and perhaps better educated farmers.

A major effort of the extension service is to disseminate timely information through public meetings. The topics covered in publications and public meetings would be heavily influenced by current research results. Any bias toward larger farms embodied in research results would probably be carried over into meetings and publications.

A national survey of county agents directed at identifying extension's farm clientele indicated: 46 percent of the farm clients had annual gross sales of under $20,000; 20 percent of the farm clients had annual gross sales of $20,000-$39,999; and 34 percent of the farm clients had annual gross sales of $40,000 and over (U.S. Department of Agriculture, 1980). Even though extension personnel would make information available to all farmers, the ones that make the most use of the research results and extension information can generally be characterized as more innovative, more aggressive, and better managers of larger farms (Paarlberg). These farmers seek information they consider to be useful to them, while discarding other information deemed to be inappropriate. These farmers are also generally vocal, which provides a feedback to research and extension personnel indicating what information had been considered useful and what information had not been considered useful. The natural response on the part of research and extension personnel has been to provide more of

the useful information and less of the information that was not useful. Consequently, research and extension activities tend to respond to users of this information, which generally are larger farms. Even though there is no overt effort made to exclude particular groups such as small farmers, the net result is that many research and extension programs become oriented toward select groups that avail themselves of the information (Paarlberg).

There has been some targeting of extension programs to small farms by providing intensive educational assistance needed by economically and educationally disadvantaged producers. Federal funds were initially provided to state extension services to assist in development and evaluation of these programs. Paraprofessionals in some instances worked intensively with small farm operators. Evaluations of such programs indicated that participants increased their farm income and improved their level of living (U.S. Department of Agriculture, 1980).

Research results would have to be randomly adopted by farms of all sizes in order to achieve "adoption neutrality." Adoption neutrality, of course would be hampered to the extent that research results and/or dissemination efforts were not structurally neutral. Even when research and extension activities are structurally neutral, neutrality may not be preserved in the technology adoption process. Adoption of new technology is dependent upon many factors including the potential profitability of the technology, extension and other information on the technology, as well as farmer characteristics such as farmers' schooling and managerial ability. In the case of technologies involving sizable capital investment, adoption is dependent on the amount of financial and natural resources controlled by farmers, as well as the general and the economic environment in which farmers operate. Many small farmers lack the time, skill, resources,

and/or economic incentives to adopt new technologies. Introducing the concept of "adoption neutrality" makes it evident that policies other than just research and extension policies contribute to structural change.

An Economic Analysis of Structural Change

A major farm structure issue is that research may result in new technologies which are adopted by some farmers but not by others producing the same commodity. In such cases those farms not adopting the technology may be adversely affected. The concern is that the adoption process is not random but is selective according to such factors as farm size, farmers' managerial abilities and farmers' financial resources. To the extent that large farmers tend to adopt technological innovations more rapidly than small farmers it is postulated that large farmers benefit more from research and extension. In order to empirically test this hypothesis a supply response model is developed and estimated for selected major commodities--dairy, beef, poultry and cash grain. The model includes several unique features:

(a) entry and exit decisions of farms are taken into account,

(b) supply response is estimated separately for small farms and large farms, and

(c) the impact of research and extension is quantified for entry and exit decisions and supply response on both small farms and large farms.

A Model of Structural Change. A model will be developed in this section to explain industry supply response while accounting for entry and exit of firms within the industry. The industry is assumed to be large enough so that no firm can affect input or output prices. Production costs are assumed to vary systematically by size of firm but randomly among firms

of a given size. It is expected that firms experiencing lower costs will continue in operation, while those firms experiencing higher costs will exit the industry. The exit decision would be based on the net present value of remaining in the industry versus shifting the production assets to an alternative use. The firm's decision would be to exit whenever the net present value in an alternative use would be greater than the net present value of continued operation within the industry.

The theoretical model is an extension of Jovanovic's industry evolution model. According to that model, the probability that a farm is in operation at time t is dependent upon its cost of production and price of output. Other factors that appear to be important in the special case of farming include firm specific characteristics such as age of operators and off-farm wage alternatives that might affect part-time farming and farm consolidation. Two factors are considered to affect its cost of production--the size of farm and research and extension expenditures within the state. With the existence of economies of size, larger farms would be expected to have lower costs, other things equal. Research and extension expenditures would be expected to increase productivity for any given level of output. The probability that a farm is operating at time t (Ψ) is determined by the following behavioral relationship.

(1) $\Psi_{it} = f(p,s,r,a,w)$

where

Ψ is the probability that the ith farm operates in time period t,

p is the price of output,

s is the size of farm,

r is research expenditures,

a is average age of farm operators, and

m is manufacturing wage as an indication of off-farm wage alternatives.

The projected level of output per farm, according to duality theory, would be dependent on output price, input prices, and research expenditures. Since the selection process determining which farms would continue to operate is not a random process as indicated by equation (1), the sample of operating farms is not considered to be a random sample. Therefore, an adjustment must be made in the model explaining the level of output per farm by taking into account the probability that the farm will operate in time period t.

(2) $q_{it} = f(p, p_x, r, \Psi)$

where

q is output of the ith farm in time period t, and

p_x is a vector of input prices.

Aggregate industry output (Q) is determined by summing expected levels of production over all farms.

(3) $Q_t = \sum_i \Psi_{it} q_{it}$

Thus the overall level of output takes into account the probability that each farm will operate and the projected level of output if that particular farm does operate.

Empirical Model and Estimation Procedure. An empirical model is developed to explain supply response by producers of selected agricultural commodities. The model accounts for the fact that some producers may exit from the industry during the period of analysis. Hence the observed value of sales for the commodity in a particular year includes values only for those farms continuing to produce the commodity.

The decision to operate within an industry in a particular year is considered as a discrete choice variable. As indicated in equation (1), the probability that a farm will operate in a particular year is assumed to be related to output price, size of farm, research expenditures, farmers' age, and off-farm wage alternatives. The equation was estimated by probit analysis (see Judge, et al.). The results of the probit analysis will be used in estimating supply response. A detailed discussion of the estimation procedure is presented in the Appendix.

The supply response model used in this analysis can be derived from the production function model used elsewhere (e.g. Bredahl and Peterson). The production function approach is not feasible here because of data limitations related to farms of different sizes. There is, however, data available on output for farms of different sizes and prices for outputs and inputs that can be applied to all farm sizes. As shown below, this information is adequate to derive the desired supply response relationships.

Through the concept of duality of cost and production functions, Fuss and McFadden, Silberberg, and Varian have shown that the cost function can be derived from the production function. Consider the traditional Cobb-Douglas production function as the basis to begin the analysis.

$$(4)\quad q = A \prod_{i=1}^{n} x_i^{a_i}$$

where:

a_i is the partial elasticity of production for the ith input

$\sum a_i = E$, the so called total elasticity of production.

Introducing input prices, the cost function is as follows:

$$(5)\quad C = A^{-(1/E)} E \prod_{i=1}^{n} a_i^{-a_i(1/E)} q^{(1/E)} \prod_{i=1}^{n} p_{xi}^{a_i(1/E)}$$

where C is total cost, and

p_{xi} represent input prices.

Differentiating this total cost function with respect to output gives the marginal cost function. Equating marginal cost with price of output and taking logarithms yields the supply function.

$$(6)\quad \ln q = 1/(1-E)\ \ln A \prod_{i=1}^{n} a_i^{a_i} - 1/(1-E) \sum_{i=1}^{n} a_i \ln p_{xi} + [E/(1-E)] \ln p$$

Data on farm numbers and production by farm type and farm size are obtained from the Census of Agriculture (U.S. Department of Commerce), as are average ages of farm operators by farm type. Farm and manufacturing wage rates are obtained from Farm Labor (U.S. Department of Agriculture) and Statistical Abstract of the U.S. (U.S. Department of Commerce) respectively. The price of land is calculated from data in Farm Real Estate Market Developments (U.S. Department of Agriculture) and Agricultural Statistics (U.S. Department of Agriculture). Stock and output prices are obtained from Agricultural Statistics (U.S. Department of Agriculture); all other prices (feed, fertilizer, seed, and fuel) are obtained from Agricultural Prices Annual Summary (U.S. Department of Agriculture). Research expenditures are obtained from Inventory of Agricultural Research (U.S. Department of Agriculture). Price and wage data are deflated by the CPI while research expenditures are deflated by the government implicit price deflator. Both indexes are reported in Statistical Abstract of the U.S. (U.S. Department of Commerce).

The study covers the 1969, 1974, and 1978 Census years and was limited to the 48 contiguous states because of data limitations. Some of the farms producing the commodity at the beginning of the period exited from the industry some time during the period, as evidenced by declining farm numbers. In some instances farm numbers increased during the period, reflecting entry of new farms into the industry. Data available for the study made it necessary that the model focus on farm numbers and not on individual farm owners. Thus the transfer of a given farm from one producer to another producer is assumed not to represent a change in farm structure so long as the number of farms is left unchanged.

Each one thousand farms within a state is considered to be the basic unit of analysis that was used in each census period of the analysis. If a state had four thousand farms in 1969 and three thousand farms in 1974, then 4 units were assumed to operate in 1969 and 3 units were assumed to operate in 1974 and an identical unit was assumed not to operate in 1974. The same units would be followed through 1978.

Estimation Results. The structural change model was estimated for two broad categories of small farms and large farms producing cash grains, dairy, beef, and poultry products. Hence, eight different models were estimated. The complete regression results are presented in Appendix Tables A-1 through A-8. In general, a high level of statistical significance is exhibited in each of the models. The explanatory power of the OLS models explaining quantity of production was generally greater than the explanatory power of the probit models explaining continued operation. For the OLS models, the R^2s ranged from 0.22 to 0.88. Although not directly comparable, the pseudo R^2s in the probit models explaining continued operation were lower, ranging from 0.19 to 0.46. The lower

explanatory power of the probit models indicates that it has been difficult using only a few sociological and economic variables to explain the entry and exit decisions of farmers. Other factors might be considered in future research in this area.

The supply price elasticities will be discussed briefly, even though these are not a major consideration in this study. Other studies have estimated supply price elasticities, so the general range of values to be expected for these parameter estimates is known. The supply price elasticities in this study are 0.307-0.642 for cash grain, 0.529-1.315 for milk, 0.838-1.069 for beef, and 0.903-3.050 for eggs. These supply elasticities are well behaved and fall within expected ranges, which gives credibility to the overall model for which direct comparisons to other empirical results are not so readily available.

The coefficients for research expenditures for all eight models are summarized in Table 2. Public research expenditures had a positive effect on continuation of operation of both large and small dairy, beef and poultry farms, but these research variables were statistically significant, at least at the 0.10 level, for only the small farm categories. Public research expenditures had a negative effect on continuation of operation of cash grain farms, with the variable statistically significant only for small cash grain farms.

In the linear regression model explaining average output per farm, the regression coefficients on research expenditures cannot be interpreted directly. Since research enters the two functionally related equations (probit and OLS), the derivatives of output with respect to research must be calculated to show the net impact of this variable on output. The formula for the derivative is shown by equation (6) in the Appendix on

Table 2. Effect of Agricultural Research on Continuation of Operation and Supply by Type and Size of Farms[a]

	Continuation of Operation	Supply Response	
	Probit Research Coefficients	OLS Research Coefficients	Research Derivatives
Cash Grains			
Small Farms	-0.262*	0.141*	0.117
	(-2.631)	(11.631)	
Large Farms	-0.119	0.118*	0.123
	(-1.684)	(8.668)	
Dairy			
Small Farms (5-49 Head)	0.326*	0.101*	0.016
	(3.928)	(11.032)	
Large Farms (50 or More Head)	0.020	0.027	0.032
	(0.108)	(0.792)	
Beef			
Small Farms (20-49 Head)	0.115	-0.011*	-0.013
	(2.489)	(-3.496)	
Large Farms (50 or More Head)	0.039	0.281*	0.281
	(0.396)	(14.863)	
Poultry			
Small Farms (400-3199 Birds)	0.317*	0.007	-0.055
	(2.967)	(0.173)	
Large Farms (3200 Birds)	0.038	0.152*	0.147
	(0.306)	(4.312)	

*Statistically significant at 0.01 level.

[a]Results presented in this table are taken from Tables A-1 through A-8. Continuation of operation is explained by the probit model and the supply relationship is given by the OLS model.

"Estimation Procedure for Structural Change." A summary of the estimated derivatives for research expenditures is shown as the last column of Table 2. The sign of the research derivative is negative for all small beef and poultry farms, indicating that research results in less output on these farms. The sign of the research derivative for small cash grain and dairy farms and all large farms is positive, indicating that public research contributes to expanded output on these farms.

The economic theory, as discussed in an earlier section of this report, indicated that producers who fail to adopt new improved technologies could be adversely affected by the price depressing effects of other producers adopting the improved technologies and expanding production. The impacts on those producers not adopting the improved technologies can be divided into two categories: (a) some of the producers reduce output and (b) others exit the industry. The positive research derivatives for both small and large cash grain farms indicated that output was expanded on cash grain farms as a result of public research on cash grains. In fact, the similar magnitudes for the research derivatives indicate that output was expanded to the same extent, on a relative basis, on both small and large cash grain farms. The dairy, beef and poultry results were similar across farm types but different from the cash grain results. The fact that the research coefficients in the probit models for small and large dairy, beef, and poultry farms were positive, although not statistically significant in every case, indicates that dairy, beef and poultry research in public institutions has not resulted in a systematic reduction in the number of dairy, beef and poultry farms during the period of this analysis. On the contrary, public research had a positive and statistically significant (at

least at the 0.10 level) effect on the continued operation of small dairy, beef and poultry farms, ceterius paribus.

This empirical work is pioneering in nature, being the first to estimate such relationships. Applications of similar or related methodologies to a wide variety of commodity groups would be helpful to policymakers.

Options for Obtaining Greater Structural Neutrality

Identification of the most desirable future farm structure is a complex issue involving political, sociological, and economic considerations. Although it is beyond the scope of this paper to describe what future farm structure is most desirable, empirical evidence has been presented on how research and extension policy has affected farm structure in recent years. These empirical results are interpreted with respect to how research and extension policy might be expected to affect future farm structure. In particular, options to achieve greater structural neutrality are discussed.

The empirical findings reported in the previous section of this report indicate that public research has contributed to fewer cash grain farms producing more output in aggregate but greater numbers of dairy, beef and poultry farms, with generally less production on the small farms and more production on the large farms, ceteris paribus. However, it was not possible to determine which process--research, dissemination or adoption--failed to achieve structural neutrality. The mixed nature of these empirical results indicates that it would be difficult to maintain

the current farm structure by simply performing more of the same type of research activities as have been performed historically when other factors such as changing relative prices and economies of size are creating needs for adjustments in the number and size of farms. Furthermore, it would be difficult to achieve a farm structure containing relatively more small farms by simply performing more of these same research activities. Some reorientation of research and extension activities would be needed to achieve structural neutrality. In particular, achieving greater structural neutrality through public research and extension would require more effort aimed at improving small farm technologies and management decisions and getting such improvements adopted by small farmers.

If greater structural neutrality is desired by our society, there appears to be two general approaches from a research and extension policy perspective to achieve such a structural goal. The general approaches are (a) using research and extension in isolation to achieve desired structural goals, and (b) using research and extension as components of a larger integrated approach to achieve desired structural goals. These major options and their consequences are discussed below.

Emphasizing Research and Extension

Achieving greater structural neutrality through research and extension would require more effort on getting new technologies in the hands of small farmers. This process will be discussed by considering alternatives affecting "research neutrality," "dissemination neutrality," and "adoption neutrality."

To provide greater "research neutrality," public research efforts would need to be focused more on those technologies that favor small farms. The

Experiment Station Committee on Organization and Policy (ESCOP) indicated that only 17 percent of current research is directed at farms producing less than $100,000 in annual sales. Madden and Tischbein indicate that small farm research is needed to find ways to increase income for limited resource farm families and to develop technologies suitable for small farms. Additional suggested small farm research includes enhancement of marketing channels for small farms; increasing information and technical assistance; studies to determine the impact of various kinds of research on the viability of small farms in various locations and types of farming; and new and better research on ways to efficiently produce a wide array of actual and potential enterprises on small farms.

It is unlikely that focusing research efforts on technologies applicable to all farm sizes would reduce structural trends. Most of the biological-chemical technologies developed in the past have been applicable to any farm size, but larger farms tended to take advantage of the developments, increasing their comparative advantage over farms (often smaller farms) that did not adopt the new technology.

Financing any increment in small farm research could come in the form of either (a) an increase in funding for agricultural research in total or (b) a reduction in other agricultural research areas. Considering the first alternative, an increase in agricultural research funding can be justified in terms of economic efficiency so long as the rate of return on this investment is greater than other alternatives. As indicated earlier, the rate of return on agricultural research in aggregate has been high, supporting expanded funding in this area (Ruttan). Although less evidence is available on the returns to small farm research, its rate of return would be expected to be lower because the magnitude of commodities produced

on small farms is much less than on large farms. Despite what rate of return estimates might show, small farm research might be logically supported on the basis of sociological factors rather than economic factors. Society might view small farm research as a way to reduce poverty and/or to improve well being of small farmers.

Increasing support for small farm research while maintaining the overall level of support for agricultural research has some major drawbacks that would result from a reduction in research applicable both to all farm sizes and to larger farms. Productivity gains over the last decade averaged 1.7 percent per year, saving consumers over $2 billion annually in food costs (Tweeten). If productivity gains were solely on farms with sales of $40,000 or less productivity gains would have to average 9 percent annually to produce benefits comparable to current levels. Such growth rates seem unrealistic, implying that consumers would probably be adversely affected by this alternative.

Increasing "dissemination neutrality" would certainly be enhanced if more small farm technology was available. Another way to increase dissemination neutrality is to target extension efforts more to small farms. Several extension programs in the last few years have been focused on small farms, often using paraprofessionals to work intensively with small farmers (U.S. Department of Agriculture, 1980). In several of the Southern states, the 1890 land-grant universities have been involved in small farm programs (Williams, 1984). The 1890 land-grant universities in general do not have an extension counterpart and are hence somewhat limited in their ability to interact directly with small farmers on a continuing basis.

As with research, benefit-cost analyses of special extension programs targeted to small farms have to take into account how the programs are to be financed. If small farm extension programs are increased at the expense of current programs, then benefits foregone from failure to continue current programs must be taken into consideration. As noted earlier, the rate of return on investment in extension activities is high and it is likely that switching funds from current programs to small farm programs would result in less consumer benefits as measured by changing food costs.

Adoption neutrality," in contrast to "research neutrality" and "dissemination neutrality," is based on decision making at the farm level. Adoption decisions are dependent on farmer characteristics including available financial and operating resources, technology characteristics including its degree of cost effectiveness or profitability, and the general economic situation. Assuming that research scientists can develop small scale technology and extension personnel can present the information on small farm technology to small farmers, the final adoption decision still has to be made by the farmer. Hence it is evident that policies other than research and extension policies are important in influencing the adoption decision. The next section discusses a broad based approach to obtaining greater structural neutrality in which research and extension policy is only one component of the overall approach.

An Integrated Approach to Structural Neutrality

A large number of factors affect the economic environment in which farmers operate and hence affect farm structure. There is some concern that an integrated approach to farm price, income, and structure policies is needed to deal with farm structure problems.

A survey of other developed countries indicated that France, Norway, Sweden, Japan, Canada, and Australia have explicit farm structure policies (Bray, Castillo, and Bjomlund). Several structural programs operate in conjunction with income stabilization and price support programs. High price supports have tended to maintain the existing farm structure in several of these countries. Land use, land tenure, and land ownership programs and inheritance laws have had significant long-run impacts on farm structure. In several cases, the government is actively involved in controlling the land resource, often by purchasing the land and then redistributing it to increase farm size and improve efficiency. It appears that each of these countries has identified its desired farm structure objectives and then instituted programs to achieve these objectives. However, many of these countries are still having problems constraining expansion of farms.

It must be recognized that in the United States the small farm category is a very heterogeneous group that includes part-time farmers, aged farmers, and full-time farmers with limited resources (Tweeten).

Part-time farmers who lack the time, scale, and/or need for additional income would not have adequate incentives to improve productivity. Aged farmers may have too short a planning horizon to improve productivity. Limited resource full-time farmers often lack the human and material resources to improve productivity.

It is apparent that an effective, comprehensive farm structure program in the United States will involve identification of objectives and potential policy instruments. Potential objectives related to farm structure might be to slow down the trend toward fewer farms resulting from farm consolidation or even to reverse the trend toward fewer farms. To be

most effective the policy instruments instituted will shape farm structure according to such objectives as they are identified. Considering the heterogeneous nature of small farms, structural programs could be targeted for the various groups. Public assistance transfer payments might be the most effective program for small farm households with aged and disabled breadwinners (Tweeten, Cilley, and Popoola). Programs for other small farms might include research and extension programs targeted to small farms, price and income programs aimed at increasing the profitability of production on small farms, and credit programs to offer more risk or venture capital to small farms. Furthermore tax policies, environmental policies, energy policies, ownership and land use policies, and/or water use policies might be modified to help achieve the desired farm structure. Also, programs aimed at income stabilization and price supports would be modified to complement rather than conflict with structural programs.

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Appendix

Estimation Procedure for Structural Change Model

The observed value of sales for a commodity in a particular year includes values only for those firms continuing to produce the commodity, and excludes values for other firms that have exited the industry. Such a selection process results in a censored sample. A censored sample is one in which some observations on the dependent variable corresponding to known sets of independent variables are not observable (Judge, et al., 1980, p. 609). Estimation of the behavioral relationship explaining average value of sales using such a nonrandomly selected sample in ordinary least squares regression would result in biased coefficients (Tobin, Anemiya, and Heckman, 1976 and 1979). Intuitively, estimated parameter bias occurs because least squares regression based on such a sample does not consider the initial decision of whether or not producers will continue to produce that commodity, but rather only the value of sales for those producers actually producing the commodity.

Since the sample includes observations on farms that continue to produce the commodity and farms that exit the industry, the model under consideration is:

$$(1a)\quad Y_{1i} = X_{1i}\beta_1 + u_{1i} \qquad \text{if } Y_{2i} > 0,\ (i = 1 \ldots T)$$

$$Y_{1i} = 0 \qquad \text{otherwise}$$

$$(1b)\quad Y_{2i} = X_{2i}\beta_2 + u_{2i}$$

where Y_{1i} is the average value of sales, Y_{2i} is a threshold variable

related to the exit decision, X_{1i} is a $(1 \times k_1)$ and X_{2i} is a $(1 \times k_2)$ vector of exogenous regressor values, β_1 and β_2 are conformable parameter vectors, and u_{1i} and u_{2i} are random error terms. Given equation (1), then

$$(2)\quad E(Y_{1i}|X_{1i},\ Y_{2i} > 0) =$$

$$Y_{1i}\beta_1 + E(u_{1i}|u_{2i} > -X_{2i}\beta_2)$$

is the regression function for Y_{1i}. Sample selection bias (Heckman, 1979) arises when estimating the average value of sales, Y_{1i}, using least squares if the conditional mean of u_{1i} does not equal zero. In general, the disturbance term, u_{1i}, in such a model will be a function of the variables X_2 and therefore will not exhibit a mean of zero. The major implication of this result is that parameter estimates β_1 will likely be biased if the estimates are based on a sample which only includes observations for which $Y_{2i} > 0$, i.e. those farms which are currently producing the commodity. To derive unbiased estimates for β_1 some means of accounting for the conditional mean of u_{1i} in equation (2) is needed.

Heckman (1979) suggests an estimation procedure for a censored sample in which Y_{2i} is an unobservable variable but X_{2i} is observed for $i = 1 \ldots T$. Heckman's instrumental variable procedure alleviates selection bias and provides parameter estimates which are consistent and asymptotically normal. The estimator results from applying least squares to:

$$(3)\quad Y_{1i} = [X_{1i},\ \lambda_i] \begin{bmatrix} \beta_1 \\ \beta_\lambda \end{bmatrix}, \quad i = 1 \ldots S$$

where X, $(S < T)$, is equal to the total number of observations for which $Y_{1i} > 0$, and

$$\lambda_i = \frac{f(\theta_i)}{1 - F(\theta_i)}$$

and,

$$\theta_i = - X_{2i} \frac{\beta_2}{(\sigma_{22})^{1/2}}$$

where $f(\theta_i)$ and $F(\theta_i)$ are the density and distribution functions of a standard normal random variable evaluated at θ_i. Heckman (1979, p. 157) suggests a consistent probit estimator for $\beta_2/(\sigma_{22})^{1/2}$ and thus θ_i and λ_i. Least squares estimates of β_1 in equation (3) are therefore functions of consistent estimators and are so themselves consistent by Slutsky's theorem (Judge, et al., 1980, p. 612). For this model the probit estimator can be written:

$$(4)\ d_i = X_{2i}\gamma + e_i$$

where $d_i = 1$ if $Y_{2i} > 0$ and 0 otherwise, γ is an estimate of $\beta_2/(\sigma_{22})^{1/2}$, and e_i is the random error.

The coefficients in the instrumental variable regression equation alone do not reflect the effect of a change in the independent variable in the value of sales. The appropriate derivative is:

$$(5)\ \frac{\partial \log Y_{1i}}{\partial X_{1ij}} = \beta_{1i} + \beta_\lambda \frac{\partial \lambda_i}{\partial X_{2ij}}$$

where X_{kij} corresponds to the j'th regressor in the k'th equation, (k = 1, 2), for the i'th firm. $(\partial \log Y_{1i}/\partial X_{1ij}) = \beta_{1j}$ for the least squares model, and,

$$(6)\quad \frac{\partial \lambda_i}{\partial X_{2ij}} = \frac{\theta f(\theta)\ (\beta_2/\sigma_{22}^{1/2})}{1 - F(\theta)} - \frac{[f(\theta)]^2\ (\beta_2/\sigma_{22}^{1/2})}{[1 - F(\theta)]^2}$$

If X_{1j} does not appear in X_2 then $(\partial \lambda_i / \partial X_{2ij}) = 0$ for the censored sample model. This result is intuitively appealing since changes in X_{1j} which do not appear in X_2 have no effect on Y_{2i} in the threshold equation.

Table A-1. Supply Response for Cash Grain on Small Farms (With 10-139 Acres)

Explanatory Variables	Probit Estimates Explaining Continuing Operations	Regression Estimates Explaining Level of Output	Derivatives for Level of Output With Respect to Explanatory Variables
Intercept	25.088 (2.057)[a]	0.147 (0.472)	
Price of Fuel		-0.959* (-11.471)	
Price of Fertilizer		0.500* (10.390)	
Price of Seed		0.010 (0.562)	
Price of Land		0.459* (19.387)	
Farm Wage Rate		0.565* (5.686)	
Price of Grain	0.208 (1.038)	0.624* (32.936)	0.642
Research	-0.262* (-2.631)	0.141* (11.631)	0.117
Age of Operator	-5.142 (-1.664)		
Manufacturing Wage Rate	-1.919* (-4.727)		
Lagged Output	1.152* (10.794)		
Lagged Operation	1.371* (7.971)		
Lambda		-0.312* (-7.785)	
R^2	0.24[b]	0.76	

*Statistically significant at 0.01 level.

[a]Student t-values are given in parentheses.

[b]Pseudo R^2 for probit equation.

Table A-2. Supply Response for Cash Grain on Large Farms (With 140 or More Acres)

Explanatory Variables	Probit Estimates Explaining Continuing Operations	Regression Estimates Explaining Level of Output	Derivatives for Level of Output With Respect to Explanatory Variables
Intercept	-2.576 (-0.274)[a]	-2.938* (-10.676)	
Price of Fuel		0.884* (10.411)	
Price of Fertilizer		0.516* (9.045)	
Price of Seed		-0.147* (-10.434)	
Price of Land		0.420* (18.324)	
Farm Wage Rate		0.009* (0.085)	
Price of Grain	-0.592 (-4.656)*	0.307* (14.698)	0.336
Research	-0.119 (-1.684)	0.118* (8.668)	0.123
Age of Operator	0.904 (0.308)		
Manufacturing Wage Rate	0.265 (1.285)		
Lagged Output	-0.186* (-2.991)		
Lagged Operation	2.702 (15.428)*		
Lambda		0.247* (3.375)	
R^2	0.29[b]	0.53	

*Statistically significant at 0.01 level.

[a]Student t-values are given in parentheses.

[b]Pseudo R^2 for probit equation.

Table A-3. Supply Response for Milk on Small Farms (With 5-49 Milk Cows)

Explanatory Variables	Probit Estimates Explaining Continuing Operations	Regression Estimates Explaining Level of Output	Derivatives for Level of Output With Respect to Explanatory Variables
Intercept	6.940 (0.594)[a]	-5.763* (-19.294)	
Price of Stock		1.053* (20.958)	
Price of Feed		-0.552* (-11.940)	
Farm Wage Rate		0.230* (3.600)	
Price of Milk	1.198 (1.384)	0.842* (13.070)	0.529
Research	0.326* (3.928)	0.101* (11.032)	0.016
Age of Operator	-4.717 (-1.888)		
Manufacturing Wage Rate	1.297* (2.820)		
Lagged Output	-1.201* (-7.349)		
Lagged Operation	5.333 (0.715)		
Lambda		0.595* (17.500)	
R^2	0.39[b]	0.76	

*Statistically significant at 0.01 level.

[a]Student t-values are given in parentheses.

[b]Pseudo R^2 for probit equation.

Table A-4. Supply Response for Milk on Large Farms (With 50 or More Milk Cows)

Explanatory Variables	Probit Estimates Explaining Continuing Operations	Regression Estimates Explaining Level of Output	Derivatives for Level of Output With Respect to Explanatory Variables
Intercept	21.030 (0.989)[a]	3.381 (2.442)	
Price of Stock		-0.126 (-0.648)	
Price of Feed		-0.435* (-2.622)	
Farm Wage Rate		1.674* (7.122)	
Price of Milk	3.325 (2.077)	0.434 (1.475)	1.315
Research	0.020 (0.108)	0.027 (0.792)	0.032
Age of Operator	-7.523 (-1.292)		
Manufacturing Wage	0.711 (0.731)		
Lagged Output	1.473* (4.012)		
Lagged Operation	0.773 (1.956)		
Lambda		-1.000* (-7.308)	
R^2	0.20[b]	0.44	

*Statistically significant at 0.01 level.

[a]Student t-values are given in parentheses.

[b]Pseudo R^2 for probit equation.

Table A-5. Supply Response for Beef on Small Farms (With 20-49 Head)

Explanatory Variables	Probit Estimates Explaining Continuing Operations	Regression Estimates Explaining Level of Output	Derivatives for Level of Output With Respect to Explanatory Variables
Intercept	-2.855 (-1.327)[a]	6.504* (78.884)	
Price of Land		0.061* (9.386)	
Farm Wage Rate		0.208* (7.075)	
Price of Feed		-0.549* (-12.255)	
Price of Stock		-0.314* (-18.839)	
Price of Beef (Lagged)	-1.042* (-5.156)	0.817* (73.547)	0.838
Research	0.115 (2.489)	-0.011* (-3.496)	-0.013
Age of Operator	1.195* (4.194)		
Manufacturing Wage Rate	0.306 (1.681)		
Lagged Output	0.167 (0.703)		
Lagged Operation	1.993* (11.438)		
Lambda		0.079* (4.551)	
R^2	0.23[b]	0.88	

*Statistically significant at 0.01 level.

[a]Student t-values are given in parentheses.

[b]Pseudo R^2 for probit equation.

Table A-6. Supply Response for Beef on Large Farms (With 50 or More Head)

Explanatory Variables	Probit Estimates Explaining Continuing Operations	Regression Estimates Explaining Level of Output	Derivatives for Level of Output With Respect to Explanatory Variables
Intercept	6.211 (2.431)[a]	5.669* (13.790)	
Price of Land		-0.189* (-6.651)	
Farm Wage Rate		1.444* (9.734)	
Price of Feed		-1.448* (-6.420)	
Price of Stock		-0.309* (-3.571)	
Price of Beef (Lagged)	-1.234* (-4.793)	1.032* (16.165)	1.069
Research	0.039 (0.396)	0.281* (14.863)	0.281
Age of Operator	0.022 (0.060)		
Manufacturing Wage Rate	0.225 (0.923)		
Lagged Output	-0.121 (-0.939)		
Lagged Operation	1.907* (8.439)		
Lambda		0.127 (1.127)	
R^2	0.19[b]	0.58	

*Statistically significant at 0.01 level.

[a]Student t-values are given in parentheses.

[b]Pseudo R^2 for probit equation.

Table A-7. Supply Response for Eggs on Small Farms (With 400-3199 Birds)

Explanatory Variables	Probit Estimates Explaining Continuing Operations	Regression Estimates Explaining Level of Output	Derivatives for Level of Output With Respect to Explanatory Variables
Intercept	-9.050* (-4.227)[a]	-0.872 (-0.806)	
Price of Land		0.088 (0.044)	
Farm Wage Rate		-0.073 (-0.285)	
Price of Feed		-1.559* (-8.694)	
Price of Stock		-0.245 (-1.547)	
Price of Eggs (Lagged)	-2.528* (-5.539)	2.558* (16.312)	3.050
Research	0.317* (2.967)	0.007 (0.173)	-0.055
Age of Operator	3.215* (7.792)		
Manufacturing Wage Rate	-0.235 (-0.709)		
Lagged Output	0.562* (4.399)		
Lagged Operation	2.126* (5.738)		
Lambda		0.357* (5.525)	
R^2	0.46[b]	0.60	

*Statistically significant at 0.01 level.

[a]Student t-values are given in parentheses.

[b]Pseudo R^2 for probit equation.

Table A-8. Supply Response for Eggs on Large Farms (With 3200 or More Birds)

Explanatory Variables	Probit Estimates Explaining Continuing Operations	Regression Estimates Explaining Level of Output	Derivatives for Level of Output With Respect to Explanatory Variables
Intercept	4.753 (1.413)[a]	-0.480 (-0.452)	
Price of Land		-0.100 (-1.918)	
Farm Wage Rate		1.561* (7.058)	
Price of Feed		0.250 (1.591)	
Price of Stock		-1.084* (-6.673)	
Price of Eggs (Lagged)	-2.145* (-3.921)	0.627* (3.420)	0.903
Research	0.038 (0.306)	0.152* (4.312)	0.147
Age of Operator	0.703 (1.654)		
Manufacturing Wage Rate	-0.888 (-2.140)		
Lagged Output	0.017 (0.110)		
Lagged Operation	1.962* (8.023)		
Lambda		0.348* (3.890)	
R^2	0.27[b]	0.22	

*Statistically significant at 0.01 level.

[a]Student t-values are given in parentheses.

[b]Pseudo R^2 for probit equation.

Background Paper No. 4

Agricultural Research and Extension Policy: Contemporary Issues

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U.S. Congress

This background paper was prepared for the assessment "Technology, Public Policy, and the Changing Structure of American Agriculture." The views expressed are those of the author(s) and not necessarily those of OTA.

Agricultural Research and Extension Policy

Much of the success of American agriculture is attributable to the creation of its agricultural research and extension system (Ruttan, Cochrane). For well over a century, the public has seen fit to invest substantial sums of money (currently about $3.0 billion annually) in agricultural research and extension at federal and state levels. This investment has been no accident. Since 1856, when the first federal agricultural research appropriations were made; 1862, when the land-grant university system was established; and 1914, when the federal-state-local extension partnership was created; agricultural research and education have been an integral part of U.S. agricultural policy (Knutson, Penn, and Boehm). The agricultural research and extension system continues to be an important contributing factor to a plentiful and low cost food and fiber supply, as well as to the positive U.S. balance of agricultural trade. For the period 1945-79, technological innovations increased agricultural output 85 percent with no change in the level of agricultural inputs (USDA, 1980).

Despite this record of success, questions are increasingly being raised regarding the performance of the agricultural research and extension system. Is there unnecessary duplication of research among the various system components? Are priorities being established in a manner whereby the highest payoff research gets done? Has a proper balance been maintained between research and extension? Is there a need for research when large food surpluses exist? Who benefits from research? Should the public be supporting research whose product, when adopted, has the effect of displacing both farmers and farm workers? Are research and extension size neutral--or, do they favor large farm operators over small farm oper-

ators? Should public supported research discoveries be patentable? If yes, who should hold the patent? With recent increases in private sector support for biotechnology research, should the level of support for public sector research be correspondingly reduced? Can the Extension Service continue to effectively transmit increasingly complex technology to farmers? Will the private sector transmit unbiased technology information?

The purpose of this report is to provide insight into the impact of research and extension programs on society. In doing so, an attempt will be made to answer several of the public policy questions that have arisen regarding the performance of the agricultural research and extension system. In a report of this length, final comprehensive answers frequently cannot be given. However, since many of these questions with regard to the research component of the system have already been the subject of considerable study, the job is easier than it otherwise would be.

Future Research and Extension Education Challenges

Increasing demands are being placed on agricultural research and extension. These demands result largely from pressures to increase food and fiber production in the face of:

- an ever-expanding world population,
- the goal of eliminating hunger and malnutrition,
- higher levels of consumer income,
- agriculture's impact on the environment,
- policies designed to expand exports,
- the desire for a safer food supply, and
- reduced availability of water for irrigation.

Technological change is required to solve each of the problems implied by these public concerns. The process of achieving technological

change involves three basic steps:

- Discovery of new ideas, concepts, and relationships;
- Development of those ideas, concepts, and relationships into products (where a product is the output of technology);
- Adoption of the products.

Discovery is primarily the function of basic research. Most of the basic research has traditionally been done in public sector, USDA, and agricultural experiment station laboratories. There appears to be a general assumption that the private sector will not support sufficient amounts of high risk basic agricultural research. The reason lies in the lack of a prospect of near-term payoff from higher risk basic research. But even this assumption is now being challenged by large private sector investments in bio and information technology.

Developmental or applied research is conducted by both the public and the private sectors. The marked increase in the quantity of applied private sector research has resulted in suggestions that public sector support for agricultural research might logically be reduced. Such a suggestion is overly simplistic. Research policy decisions require an understanding of the relative payoffs from various types of research, the interrelationships between basic and applied research, and the types of research undertaken by the public and private sectors (White).

The function of encouraging technology adoption has traditionally been shared by the public and private sectors. In the public sector, extension educators work directly with farmers to test and demonstrate the usefulness of new products flowing out of both the public and private sectors. Private firms tend to concentrate their adoption strategies on more conventional promotion and advertising strategies.

Over time, the effort and resources required to achieve a technological breakthrough, as a general rule, increase. This is the case because the simpler problems naturally tend to be solved first. More difficult problems require more complex tools of analysis and thus a larger research commitment in terms of time, effort, and resources.

Illustrative of this increased complexity is the entry of agriculture into the contemporary biotechnology era. For years, agriculture has depended on chemicals to control pests, diseases, and weeds. These chemicals have been applied without a full knowledge of either precisely how they work or their full environmental impacts. This practice has increasingly been questioned as chemical residues have been associated with environmental contamination and safety concerns.

Biotechnology research has increased the understanding of the specific effects of chemicals, such as atrazine on weeds. As a result of such research, it is becoming possible to engineer control agents designed to deal with specific problems. All agricultural plants could, for example, potentially be made resistant to "Roundup" herbicide. With all cultivated plants resistant to a particular chemical and all undesirable grasses susceptible to it, the potential exists for nearly complete control of grassy weeds on a farm. With improved weed control, higher output and/or reduced inputs would result. In addition, fewer chemicals that are less environmentally hazardous could be used in smaller quantities per acre. The result could be a safer food supply and environment with fewer valuable resources utilized and a higher level of output.

To achieve these benefits, large investments will need to be made in basic research. Much of this research utilizes techniques not common to agriculture. New scientists having modern biotechnology research skills

must be trained and existing scientists retooled. Laboratories and related equipment are necessarily more complex and expensive. The educational levels of the producer clientele must be improved to adopt and effectively utilize the more complex new technologies.

Such needs will not be accomplished overnight. Research and education are, of necessity, long term processes. Interruptions of research and education create gaps in the flow of technology into agriculture that are of a considerably longer duration than the interruption itself. For example, if a line of research designed to pinpoint molecular defects in genes that make poultry and cattle vulnerable to leukesis (a form of cancer) were interrupted, it could increase the time required for discovery, development, and adoption of leukesis control methods by several years.

Agricultural research and extension education programs compete with other demands for both public and private funds. In the private sector, support for research is dependent on overall firm profitability and the potential for near-term cost recovery and contribution to profits. When firm profits fall, research funds have traditionally been among the first to be cut. This variability in private sector research investment increases the need for stability of funding by the public sector. It also increases the need for public sector policymakers to evaluate the comparative payoff from various forms of government expenditures--recognizing that all requests for government assistance cannot be satisfied. Weighing the payoffs from the many alternative demands on the public treasury may be the most complex task facing policymakers.

Components of the Agricultural Research and Extension Education System

The U.S. agricultural research and extension education system contains a large number of research and education agencies that fall into

five groups:

- USDA,
- Other federal agencies,
- Land-grant universities,
- Nonland-grant universities,
- Private firms, individuals, and foundations.

These agencies can be viewed both from the perspective of the sources of funds and from the perspective of the performers of research and educational activities (users of funds)(Figure 1). Each of the components of the agricultural research system has its unique role, although all are interrelated and tied to the central objective of technology discovery and transfer for the benefit of farmers and society as a whole.

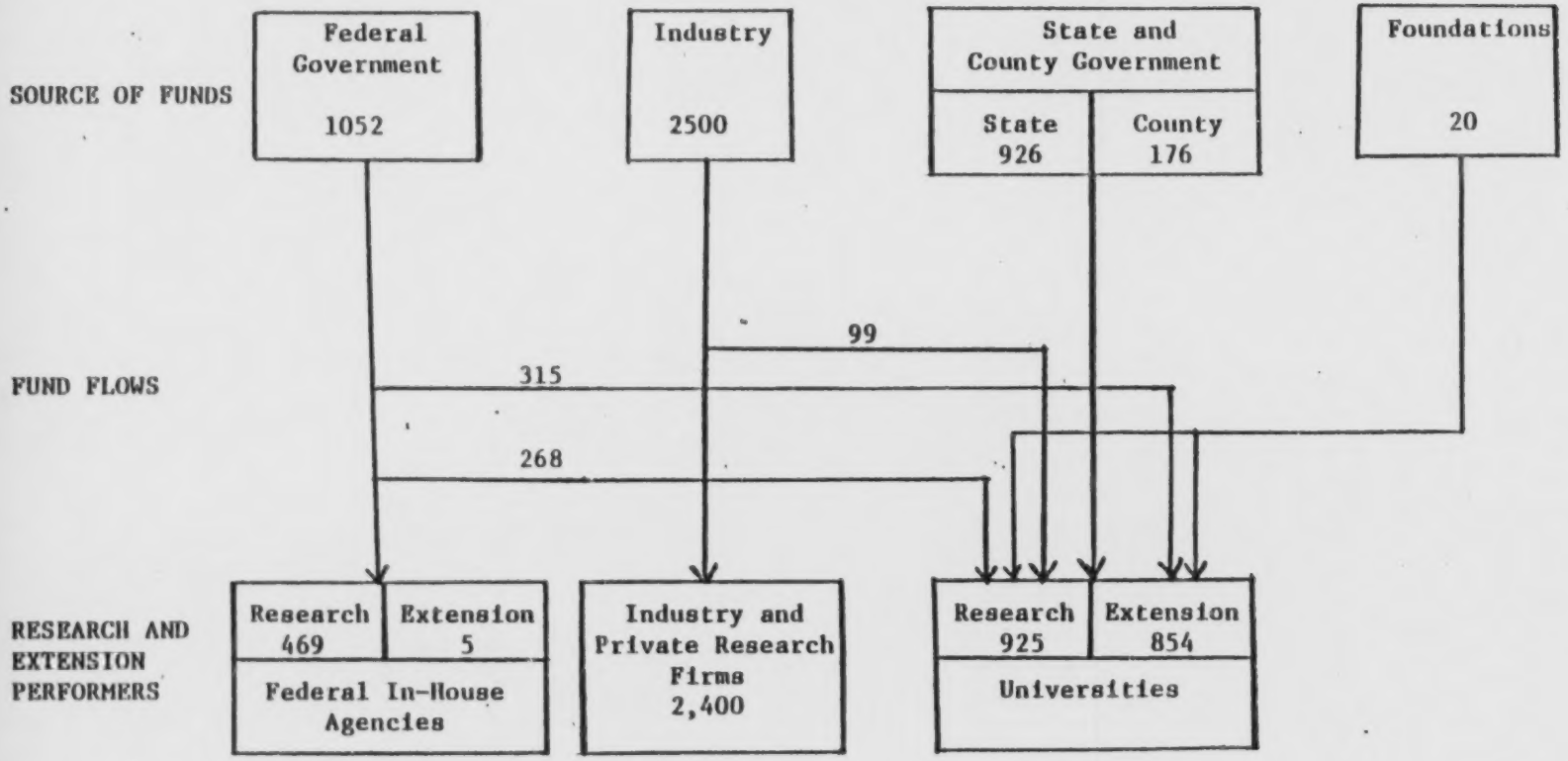
USDA

The 1977 farm bill designated USDA as the lead federal agency for research, extension education, and teaching in the food and agricultural sciences. This action confirmed into law what had been true since before the turn of the century. This does not, however, mean that USDA provides a majority of the funds for these functions. In fact, the proportion of funds provided by USDA for agricultural research and extension has declined from about 54 percent in 1966 to 47 percent in 1982 (CSRS).

Research

USDA provides funds to both its own research agencies and to universities. Its own agencies include mainly the Agricultural Research Service and the Economic Research Service, which utilize about 75 percent of USDA's research funds. The remaining 25 percent go almost entirely to universities. Most of the university funds go to land-grant universities

Figure 1. Agricultural Research and Extension Funding (in million dollars), 1982



(1862 and 1890). USDA funds to nonland-grant universities are limited to relatively few competitive grants used to support high-priority research.

USDA's agricultural research is carried out at 148 locations spread across the United States. About two-thirds of USDA's agricultural research scientists are located in its own laboratories, with the remainder being located in the land-grant universities' agricultural experiment stations. In contrast to its agricultural research, USDA's economic research tends to be heavily concentrated in Washington, D.C. This concentration is increasing with the recent policy decision to reduce the size of the ERS field staff.

Over time there has been considerable debate regarding the role of USDA in both agricultural and economic research. During the 1950s through the 1970s, agricultural research had a tendency to become increasingly decentralized with a proliferation of agricultural research facilities located throughout the United States. In addition, administration was decentralized with substantial authority for program development being established at the regional level. As a result, questions arose regarding the role of USDA and potential duplication of research functions between USDA and the land-grant universities (OTA). After a number of special studies and recommendations, the issue of the role of USDA in agricultural research came to a head in the debate on the 1977 farm bill when the Congress designated USDA as the lead agency of the federal government for agricultural research and directed the Secretary of Agriculture to coordinate all agricultural research, extension, and teaching activities conducted or financed by federal funds.

The 1977 farm bill did not specifically address the functions of USDA versus the land-grant universities, although it established a Joint Coun-

cil on Food and Agricultural Sciences and a National Agricultural Research and Extension Users Advisory Board to assist in planning the research and extension program agenda. The responsibilities of the Joint Council include a formidable list of tasks:

- evaluation of research, extension, and teaching program impacts,
- identification of high-priority research,
- development of memoranda of understanding among the participants,
- establishment of priorities,
- recommendation of responsibilities for research, extension, and teaching programs, and
- summarization of achievements.

In a recent comprehensive Office of Technology Assessment study, it was concluded, "There is concern whether the functions assigned the Joint Council are attainable." (OTA, p. 147).

The Users Advisory Board has a somewhat less formidable task of determining the needs and priorities for agricultural research and extension. Its major mandates include:

- reviewing USDA's policies, plans, and goals for research and extension,
- examining relationships between private and public sector research and extension programs,
- recommending policies, priorities, and strategies for research and extension, and
- assessing the distribution of resources and allocation of funds for research and extension.

While it is generally agreed that the functions of the Users Advisory Board are more attainable than those of the Joint Council, the impact of

the Board in establishing research priorities is unclear (OTA, p. 146).

In addition, OTA concludes that there is still no satisfactory long-term process for evaluating existing research activities, potential research opportunities, and for the development of a new set of research priorities (OTA, p. 147). At the same time, OTA recognizes the potential for excess planning and too much organization. Reality suggests that the budget allocation and hiring decisions are the major tools available to a research administrator in influencing research decisions. Specific decisions on what research is to be undertaken generally are made by the research scientists. Agricultural research is sufficiently complex that research administrators have difficulty evaluating the relative merits of particular projects. The administrators' comparative advantage is in establishing policy; organizing to get the job done; obtaining and allocating funds; and coordinating to eliminate unnecessary duplication (OTA, p. 139-142).

It is often assumed by the general public and even by policymakers that duplication is undesirable. However, research requires confirmation that a discovery is not simply a chance occurrence. Therefore, research must be replicated--a form of duplication. To this extent, duplication is an integral part of the scientific process.

One of the most important contemporary issues that the federal government has to deal with is that of establishing broad priority research and extension needs and the roles of the components of the research and extension system. The Joint Council and Users Advisory Board, if given time and sufficient encouragement to perform, have the potential for effectively dealing with the priorities issue. Positive progress is indicated by the Joint Council's *Needs Assessment for Food and Agricultural Sci-*

ences.

The primary question regarding the roles issue involves the line of demarcation between USDA and land-grant programs. This issue has been treated quite differently by research and extension. The OTA study logically concludes that *USDA research should concentrate on agricultural problems important to the Nation that no one state or private group has the resources, facilities, or incentive to solve* (OTA, p. 95). Such a role can logically be assigned to both USDA's Agricultural and Economic Research Services. In the case of its agricultural research, a shift to concentrating on only national and regional problems would represent a marked departure from past decentralization policies involving increasing emphasis by the Agricultural Research Service on research having a state or local focus.

Extension

As the rate of technological change accelerates, access to information plays a more important role in agricultural productivity and farm survival. In the evolving bio and information technology era the trend is to substitute information for time, capital, labor, land, and energy throughout agriculture (Christenson and Warner). In the agricultural research system researchers have traditionally been the producers of new technology and extension has been the adoptors, evaluators, disseminators, and trouble shooters. *Extension personnel are the agents of technology transfer.*

An accelerating rate of technological change places increased demands on performance by extension. This makes it more important that the Extension Service sort out its priorities.

Available evidence suggests that the progress of the agricultural research community in establishing priorities is more advanced than that of extension. The agricultural research community has been extensively

studied and critically evaluated in a series of projects extending back to the mid-1960s. This series of internal and external analyses, has led to adjustments in the distribution of the research system's resources in recognition of potential advances evolving from the bio and information technology era.

Similar progress is not apparent in extension. Identified national extension objectives play little role in program development at the state and local level (Marshall et al. p. 83). This is the case because most of the extension planning takes place at the local level through advisory committees and other forms of direct contact with clientele (Marshall et al. p. 83). Yet that hardly eliminates the need for the setting of national plans and priorities. One major Congressionally mandated extension evaluation project culminated in a series of reports that concentrates more on past benefits than on future needs, priorities, and required adjustments (Extension in the '80s). There is relatively little reference to the functions or programs of extension in the reports of either the Joint Council or the Users Advisory Board.

Federal extension has dramatically deemphasized its direct education role in the past 20 years (Hyatt, p. 17). While at one time, federal extension specialists were generally viewed as having a vast subject matter base in their own right and were frequently called upon to engage in staff training and conduct educational programs, today these specialists are viewed more as program leaders, coordinators, and facilitators. The technology transfer and education function is thus left to the state specialists and agents. These changes were at least partially forced by reductions in personnel ceilings and limited appropriations. Regardless of its cause, this change in strategy has not been beneficial to the over-

all national extension education program. Not only has there been a lack of progress in national planning and needs assessment, but also the quality of educational service to the states has deteriorated.

As in research, there are issues of national significance that the USDA Extension Service is better able to cope with educationally than are the states. While ultimately the states must still take the leadership in extending these programs to farmers, USDA extension can play an important role in making the information and related educational materials available on a timely basis. (For another perspective see Hyatt, pp. 17-18.) This role is currently being played on, at best, a spotty basis. The need is particularly critical in facilitating technology transfer between USDA research agencies and the state extension services as well as among states. Facilitating communication between the USDA and state specialists should be a key mission of USDA Extension Service. Unless this function is adequately performed, it encourages federal research agencies such as ARS to develop their own outreach programs. The need is for increased integration of the research and extension function--not greater fragmentation.

If it were decided that the USDA Extension Service should have a portion of its staff who were state-of-the-art national program leaders, the following changes would be required:

- Support for federal extension would need to be substantially increased.
- The designated leaders would have to be recognized as national extension program coordinators and be provided compensation consistent with that role.
- The program leaders would need to have access to resources whereby

researchers and state specialists could be pulled together to develop state-of-the-art educational materials that could be used in all states.

Other Federal Agencies

While other federal agencies have become more important sources of funding for agricultural research done in universities, they still provide less than 3 percent of the total agricultural research funds. The main sources of these funds are the National Institutes of Health, Department of Defense, Department of Energy, NASA, and the National Science Foundation. The National Institutes of Health and the National Science Foundation support basic university research, largely in the biotechnology area. Their grants tend to go to leading scientists working on the frontiers of promising new areas of basic research.

Land-Grant Universities

The land-grant universities represent a joint federal-state partnership in research, extension, and teaching. Land-grant universities (1862 and 1890) perform the majority of total public sector agricultural research. About 52 percent of their funds are from state appropriated sources--a marked increase from the past. Fourteen percent were formula funds; 19 percent were other federal funds; and 16 percent were from farm sales, private grants, and contracts.

Research

Land-grant university research is performed primarily in the academic departments (animal science, soil science, agronomy, agricultural economics, biochemistry, etc.) of the universities. As such, it combines the training of future scientists (graduate and undergraduate) with the

research program. Having the research scientists teaching in classrooms increases the relevance and timeliness of what is being taught in the land-grant universities.[1]

Research planning and priority setting is much more decentralized in the land-grant university system than it is in USDA. This decentralization results largely from the number of research institutions involved, the orientation toward problems of the state, the increased proportion of funding from individual states, and the higher level of academic freedom afforded university scientists compared with most federal and private sector scientists.

University administrators influence the research that is done in the universities largely through the planning and budgeting process. Most land-grant universities now have or are developing long-range research plans. These plans are normally developed from the scientist up rather than from the administrator down. Through the funding, position description, and hiring process, administrators achieve their research priorities and goals.

However, it is easy to overstate the amount of influence exercised by research administrators in universities. Reality suggests that once a research scientist is hired, the major decisions on what research is to be undertaken are made by that scientist. The scientist develops project proposals, gives reasons for the required level of support, and then, within the limits of the available budget, decides what specific research is undertaken.

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[1]The same reasoning can be applied to split appointments involving extension and research or to extension and teaching. In each instance, relevance and timeliness are fostered.

This is probably as it should be. Because of the increased complexity of projects, Experiment station directors, and other high level research administrators are frequently not in the best position to evaluate the relative merits of particular projects. The more removed the administrator's training and expertise is from that of the scientist, the more imperfect is his or her level of knowledge in dealing with specific research problems. Academic heads of departments are thus generally in a better position to judge the potential value of specific research than are experiment station directors (Knutson, Paarlberg, and McCalla).[2]

Having said this, some hold the view that scientists are becoming more isolated in basic research (Marshall, et al., p. 37). At the same time, administrators are accountable for the performance of the system in meeting public needs. They must develop a sense of the broad needs of the public and build the case for continued public support. A delicate balance must be struck between the perceived needs of research administrators and the scientists. In a system where communication is good, these perceived needs should converge. In fact, communication is the key to the performance of any system--particularly one that depends on another unit of the system for information. This is a reality at any level of the system (among researchers) or at different levels of the system (between administrators and researchers or between research and extension).

In this setting, the potential for unnecessary duplication of research among universities and between the state and federal levels is reduced by communication and the reward system within the scientific community. There is little or no reward in the scientific community for

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[2]The same reasoning can also be applied to administration of extension programs -- those closer to the work are better able to evaluate it.

research that simply duplicates what has already been discovered and confirmed. A failure to advance the frontiers of knowledge becomes the basis for outright rejection of proposed scientific publications used as criteria for promotion and tenure. Communication within professional societies provides an important information base on which future research decisions are based.

One avenue for research communication that has been substantially curtailed by restricted funding and the way funds are handled within the system is regional research. Regional research allows scientists who have mutual interests in a problem area that is larger than a single state to work together. By bringing these scientists together, the critical mass of knowledge, research skill, and resources can be assembled to tackle a particular problem.

However, persistent problems have existed in fulfilling the potential payoff from regional research. The reason lies in the reality that even earmarked regional research funds generally are handled by universities in the same manner as other funds. In most states, scientists or departments receive no additional support for engaging in regional research activities. As a result, scientists must conduct, often more costly, regional research with the same funding base. When regional research funds were relatively plentiful, regional research was frequently undertaken and completed because of scientist initiative and the perceived administrative obligation to support regional research. But as research budgets tightened, the interest of both scientists and land-grant universities in regional research declined.

Those who suffer the most from the declining interest in and commitment to regional research are the smaller, less well financed land-grant

universities. To begin with, these universities frequently do not have the critical mass of research talent required to tackle larger research problems. They can, however, get involved on a regional basis. In contrast, the larger universities are more likely to have that critical mass. As a result, in the absence of regional research, the larger universities are in a position to compete for the grants involving priority research on the cutting edge of knowledge.

The superior ability of larger universities to compete for grants combined with the increasing complexity of agricultural research has, from time to time, led to proposals for the establishment of universities that are regional "centers of excellence" in either specific or broad areas of agricultural research (Kendrick). The center concept was expanded by Marshall in recommending the establishment of Centers of Research and Extension Excellence to methodically analyze, synthesize, and disseminate research findings as well as identify high priority research needs (p. 100).

It can be argued that the "marketplace", combined with contemporary public and private research funding policies, is already leading to the development of such centers. Questions, however, exist regarding whether the "marketplace" will generate enough centers of excellence and whether the result will be the creation of a set of "have and have not" university research and extension programs. Since the land-grant universities are public institutions, it would appear appropriate that this be an overt public policy decision rather than being left to the "marketplace".

Extension

Extension education of farmers is also an integral part of the land-grant universities' functions. Extension receives about 63 percent of its

funds from the states and county sources with the remainder provided by USDA, largely under formula funds.

It cannot be assumed that once research findings are available, they will be quickly and effectively put to use.[3] How to apply new research findings is seldom obvious. The process of developing and utilizing research is complex and requires a close working relationship between the research and education functions. While much of the development of discoveries might readily be viewed as the primary responsibility of the private sector, extension plays a critical role in alerting farmers to new discoveries and products, evaluating them, and determining how they can best be utilized in combination with existing products and techniques. This is particularly true of the vast majority of farmers (likely at least 95 percent of them) who do not have direct access to research results and do not require extension interpretation of them.

Because of these complexities, extension activities go beyond a public information role. At the state level, extension has technically trained applied scientists (generally referred to as specialists) who are headquartered primarily at the land-grant university. These scientists may also have research and/or teaching responsibilities. From an extension perspective, they are generally referred to as specialists. Their extension role is to develop educational programs, prepare applied publications, conduct meetings, and provide technical assistance at the request of county staff.

Extension is not only involved in educating farmers but also in pro-

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[3]This analysis is limited to the agricultural component of the extension program. Other functions include home economics, 4-H, and community development.

viding an important "feedback loop" to the scientists concerning their problems and further needed research. The proximity of extension specialists to research scientists is critical both in terms of developing a working knowledge of the scientific developments and in closing the "feedback loop" between extension and research.

Available evidence suggests that the feedback loop concept is operating in a less than satisfactory manner. Marshall found that extension's ability to influence what research was done in the agricultural research system was less than adequate (p. 5). The study projected that more research coordination problems could be anticipated with expected increased orientation toward basic research. This finding appeared to be the main origin of Marshall's recommendation for the need for Centers of Research and Extension Excellence.

Because of its direct contact with agricultural producers and agribusiness clientele, extension programs tend to be more "grass roots" oriented than is research. In most states, educational needs are determined by predominantly producer advisory committees. Programs are then developed to address these needs using county agent and state specialist expertise. In addition, individuals from the private sector are often called upon by extension to provide a working knowledge perspective on solving particular problems.

State extension specialists are normally highly skilled scientists trained at the Ph.D. level in specific agricultural disciplines such as agronomy, animal science, entomology, or agricultural economics. In addition, these scientists develop skills in educational methodologies including the ability to utilize computer and other electronic technology, as it becomes available, to deliver research findings in an educational programs

context. With these interdisciplinary skills, specialists develop educational programs designed to fill the needs of extension's clientele. This may involve the preparation of education materials (including the development or adaptation of computer software), bulletins, press releases, radio and/or television tapes. Such educational materials may be used directly in farmer and rancher programs, or they may be used in training county agents who in turn work with farmers.

Of equal importance to its educational meeting activities, extension programs are importantly based on the *result demonstration concept.* The typical result demonstration involves the planting of different crop varieties, application of different fertilizer levels, or the application of different pest control methods to relatively small field plots of land on an actual farm. The result demonstration is open for inspection and field tours are periodically conducted for interested farmers to observe the progress of the crop.

Result demonstrations are not limited to products developed in university laboratories. As private sector branded products enter the market, they are also utilized in result demonstrations to compare their effectiveness with established products and practices. Extension thereby serves as a public sector new product and/or new practice evaluator. Performing this function avoids the need for farmers to individually determine whether new products meet manufacturers' claims. Producer costs associated with new product evaluation are thereby significantly reduced. Perhaps more important, new product/new practice testing and education materially reduce losses due to less than optimal input combinations.

With renewed emphasis on basic agricultural research, substantial concern arises over the potential for the development of an applied

research gap (Christenson and Wagner, Marshall, and Feller et al.). This happens as applied scientists are attracted into higher reward basic research leaving a question of who does the applied research. The potential for such a gap may be reduced by increased private sector interest involvement in biotechnology research and development. However, as the private sector performs a larger share of the applied research, extension has the potential for becoming even more involved in the evaluation of technologies and products flowing out of the private sector. Without such evaluation individual farmers and ranchers will incur the costs of experimenting to determine the optimum input combinations to use in production. These costs will be converted into reduced farm numbers (for those who used the wrong input combinations), higher food costs, and reduced competitiveness in international commodity markets.

Substantial challenge is involved in extension's adjusting to this new role. While in some states technology and/or extension are already deeply involved in the evaluation of new products, in other states product evaluation has been primarily an experiment station function. In the future, experiment stations will likely be doing less of this work. Extension's responsibilities will correspondingly increase. This increased responsibility will require a larger specialist staff with modern scientific training. Some states may be inclined to forego the responsibility of getting involved in conflict-oriented product evaluation programs. Some probably already have.[4] To the extent that this occurs, the usefulness of extension to the farmer clientele will decline. Leader-

[4]The problem of foregoing conflict-oriented product evaluation is by no means limited to extension. For example, private firms supporting university research may place restrictions on the university's conducting and/or publishing evaluations of impacts and/or economic feasibility of particular discoveries.

ship at the federal level will be required to assure that tehnology transfer is facilitated in the farmer interest.

As agriculture becomes more complex, filling the gap between research and extension will require a larger role for extension in applied research. This is already occurring. Marshall found that 56 percent of the extension agriculture specialists with 100 percent extension appointments are involved in applied research. Despite the need for extension involvement in applied research, the Smith Lever Act provides no explicit authority for extension conducting research. An amendment to the Smith Lever Act would resolve this uncertainty as to the legality of ongoing research done by extension and pave the way for improved performance of extension in an increasingly complex agriculture. The intent of such an amendment would simply be to clarify extension's role in the process of technology transfer, not to duplicate the mission of the experiment stations.

Extension has a regional counterpart to research where specialists meet to develop educational materials on a multi-state basis. As in research, the funds committed to such activities (frequently referred to as "special need" or "pilot project" funds) have been substantially curtailed. The decision to reduce these funds occurred during the late 1970s when the Science and Education Administration was in control and when federal funding was being substantially squeezed. As a result, communication among extension specialists in different states is more limited, and the quantity of educational materials produced by regional committees has been substantially reduced. Once again, this occurrence has not had as much of an adverse effect on the educational programs of the larger, better funded universities as it has had on the smaller universities.

At current funding levels, one of the most difficult issues facing extension is limiting its role and coverage to those functions for which it has the greatest expertise (Feller). *Without criteria for limiting the role of extension, there is danger that extension activities will become so dispersed and out of focus that their effectiveness will be impaired.* Danger exists that whatever the problem, whether related to agriculture or not, extension is called upon to solve it. In the process, extension could become more of a social program than an instrument of technology transfer.

This is not a new issue but rather a continuing and progressively more complex one. It is made more treacherous by the politics of funding and the reality that once a new program is established it develops its own constituency and is difficult to cut back (Feller). It is not possible for extension to be everything to everybody no matter where the individual is located, particularly in times of limited resources. Yet, additional functions are frequently dictated by political realities at the federal, state, and local levels. For further discussion of the difficulty in delimiting the clientele and roles of extension see Hyatt, pp. 14-19 and 33.

The Joint Council has not given sufficient attention to the role of extension. As a starting point for defining that role, it must be remembered that the root of extension is research. Similarly, extension is a primary outlet for research, after an appropriate level of product development. Extension is, therefore, delimited by the scientific endeavors of the research components of the agricultural research system, including both the public and private sector components. This delimiting role is illustrated in Figure 2.

The core mission of extension is, therefore, one of developing, extending, and

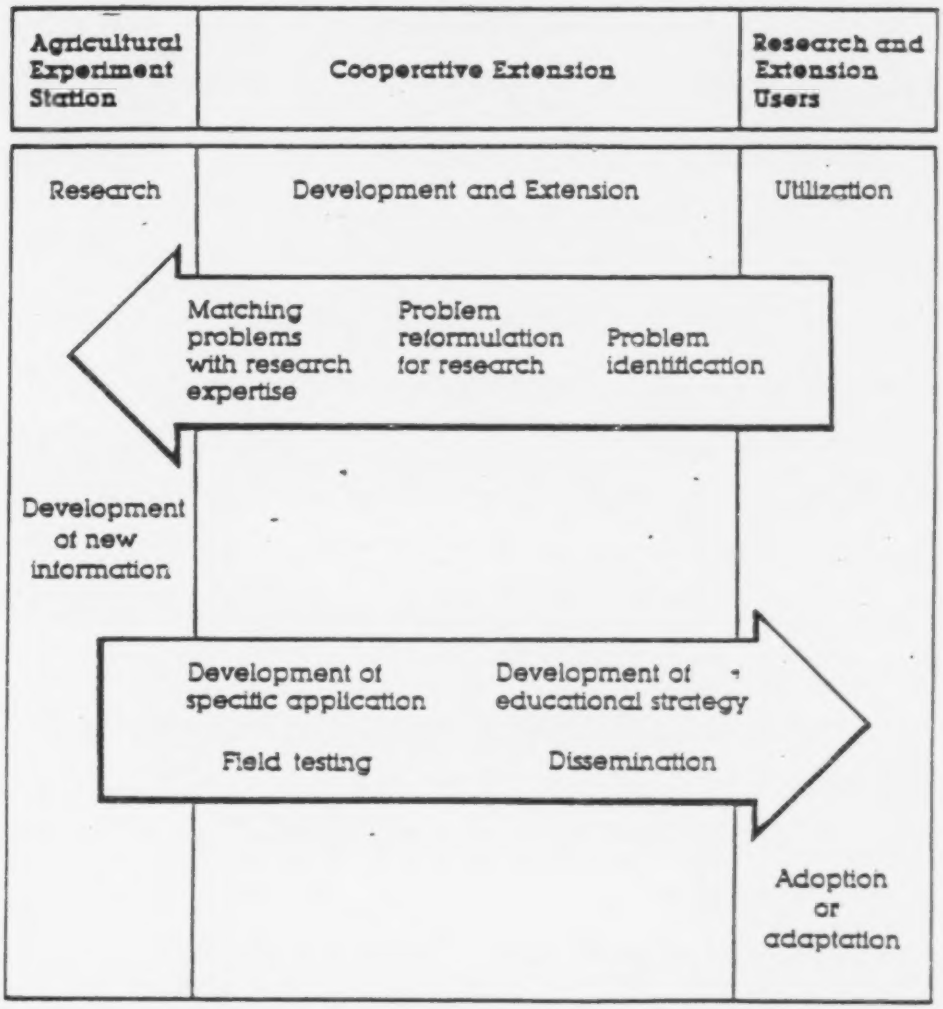
bringing about the use of research-based knowledge. The core source of that knowledge is the agricultural experiment stations. Viewing extension in a broader context than this runs serious risk of reducing its overall effectiveness (Feller). This is particularly the case when it is recognized that extension is likely to play an increasing role in filling a portion of the gap between research and extension. Another dimension of this role problem involves the tendency for the experiment stations to become more involved in "extension type" education programs as a means of gaining public recognition and support. Considerable care must be taken not to foster such duplication of efforts.

Research that is done in the land-grant universities is in direct proximity to extension specialists. It, therefore, can be directly channeled into the state extension program. USDA research often does not have the same proximity. This sometimes creates an incentive for the USDA research agencies to reach out and develop their own educational channels. Such initiatives generally amount to an unnecessary duplication of effort.

USDA's research agencies that do not have direct channels of communication with extension need to work at developing them. Perhaps the most important such communication channel is field staff, offices, and laboratories located on land-grant university campuses. Interestingly, the Economic Research Service has moved to pull most of its field staff into Washington--a strategy that runs directly in conflict with the need to improve communication.

As indicated previously USDA Extension can also play a role in facilitating communication between the USDA research agencies and the state extension specialist. *However, even maintenance (to say nothing of needed strengthening) of this role has been rendered impossible by the previously discussed*

Figure 2. Research and Extension Roles in the Technology Discovery and Transfer Process.



Source: University of California, Cooperative Extension Long Range Planning Statement, (Berkeley, August 1982) p. viii.

deemphasis of the role of USDA Extension's staff in subject matter education.

Nonland-grant Universities

Nonland-grant universities are defined as including a broad range of higher education institutions ranging from strictly private and autonomous state universities having little or no direct relationship to agriculture - to public state universities having agriculture, forestry, and food related programs but not having land-grant status (1862 or 1890). Some of these institutions have had significant applied research programs in agriculture since their founding. For most, however, their major expertise lies in teaching and research in the basic and social sciences. When agriculture entered the biotechnology era, some nonland-grant universities such as Stanford were ahead of the land-grant universities in terms of having the discipline scientists (such as molecular biologists and biochemists) who were involved in basic biological research having potential application to agriculture.

The nonland-grant universities support their research programs through state appropriations, government grants, endowments, foundations, corporate grants, and contracts. Outstanding scientists in the nonland-grant universities often receive biological research support from government institutions such as the National Science Foundation and the National Institute of Health. The 1977 farm bill opened up USDA competitive grant research to proposals from the nonland-grant universities.

Nonland-grant universities do relatively little in terms of extension-type adult education programs. Involvement in such programs is largely limited to "public service" conferences and adult outreach programs held near these universities or community colleges. Such services may be provided free as a public service, on a cost basis, or under con-

sulting arrangements with individual faculty members.

Private Sector Research

The land-grant university system was established largely because it was concluded that in a decentralized competitive structure, the private sector would not have the economic incentive to provide the level of funding needed to maintain an efficient, viable agriculture. Despite many changes in the structure of agriculture since the founding of the land-grant system, this premise went largely unchallenged until the 1970s. The presumption was that agricultural firms would not undertake sufficient basic research and applied research to keep American agriculture efficient, productive, and competitive.

Until recently, private sector research, therefore, has been limited largely to providing a small number of grants for university research and private sector developmental research associated with the introduction of new products. As a result, private sector grants for agricultural research have historically come primarily from foundations such as Ford and Rockefeller. With the advent of biotechnology, private firm interest in agricultural research increased sharply. While much of this interest appears to be a spin-off from biomedical human research, substantially expanded resources have also been committed to plant and animal reproduction designed to produce new varieties or expand the rate of genetic improvement. In addition, increased interest is being shown in developing disease and insect resistant plants as well as in more organic methods of pest control.

One of the major reasons for this expanded private sector interest in agricultural research has been the extension of patent rights to plant varieties and other biological discoveries. These rights, in turn, gave

rise to increased private sector interest in supporting university research where the potential exists for capturing the benefits in terms of the resulting patented discoveries. Because such arrangements hold the potential for substantially changing the basic public service nature of the land-grant system, a separate section of this report is devoted to the implications of increased private sector involvement in biotechnology research. These implications are by no means limited to research, but also affect the overall thrust of extension education and the availability of new research knowledge to extension.

The current magnitude of private sector commitment to agricultural research is largely unknown. Studies that have been done suggest that it may approach $3 billion, particularly with the recent increases in private funding (National Agricultural Research and Extension User's Advisory Board, p. 59). *That makes the private sector research commitment approximately equal to or potentially larger than the public sector commitment. This represents a major shift in the magnitude as well as the allocation of agricultural research toward private sector dominance.*

Approximately half of the private sector research budget is spent on production agriculture and half on food production or post-harvest technology research. Private sector research resources are obviously devoted to those areas having the highest short-run profit potential. Also, despite recent large increases in private sector agricultural research, questions remain as to the long-term willingness of private sector firms to invest large sums of money in agricultural research and the breadth of such research. As noted previously, there has been a distinct tendency for private firms to cut back on research first in times of adversity.

Private Sector Promotional and Educational Programs

The private sector is playing a more important role in education (Christenson and Wagner, p. 11). For most agribusiness firms, this role is pursued in conjunction with their efforts to promote the products and/or services that they market. The educational value of these promotional activities is more in terms of alerting farmers to the availability of new products, than in objectively evaluating the performance of those products.

The burden of new product evaluation then falls either on the farmer (through trial and error) or on the extension service (through result demonstration).[5] While the extension involvement is more efficient, in the biotechnology era there is potential for increased antagonism between private sector firms and extension. This potential results from extension's evaluation of the comparative performance of new biotech products. Extension testing will not be appreciated by firms found to produce products having relatively lower levels of performance.

With a few important exceptions such as integrated pest management (IMP) checkoff programs, private sector direct financial support for agricultural extension programs has been limited, but appears to be growing. It might be argued that limited private sector funding is essential to keeping extension education programs objective. However, there may be greater dangers in increased private sector funding of extension than of research. In both cases it is critical that the objectivity and avail-

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[5]A considerable amount of new product testing is also done by the university research community either under contracts, grants, or consulting arrangements. While product testing at one time was an important component of experiment station research, it is considerably less important today.

ability of information flows be maintained.

Two of the more important private sector supporters of extension programs are the Farm Foundation and the Kellogg Foundation.[6] Both of these institutions are maintained largely by endowment grants. Each foundation has played particularly important and unique roles during the recent period of reduced funding for extension programs.

The Farm Foundation has played a particularly critical role in filling the void created by the reduction in funds available for communication and program development on a regional basis. Its support of regional extension committees in the areas of farm management, marketing, policy education, and community development has frequently become the only point of contact and coordination among specialists in neighboring states. However, the pressure on Farm Foundation funding has become increasingly intense as federal extension decisions not to fund meritorious projects become more prevalent.

The Kellogg Foundation periodically has attempted to fill a portion of the void left by the reduction of Extension Service pilot project funds. While Kellogg continues to support what it perceives to be the most innovative proposals for educational program development, an increasing backlog of proposals has developed with little hope of being funded on a timely basis.

Increased pressure on funding from public and unbiased private sector sources discourages new program development by extension specialists.

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[6] General farm organizations and commodity groups have been important supporters of both research and extension programs at the federal and state levels--this support has, however, been largely one of influencing federal, state and county government appropriations. This is an important private sector role that is frequently not recognized.

Potential and existing extension employees are increasingly being attracted to research positions and/or the private sector. A large infusion of new private support, *without a vested interest,* to institutions such as that provided by the Kellogg and Farm Foundations appears unlikely. The IPM checkoff concept may hold promise for increased direct producer funding of specific educational programs. The only remaining option then becomes the establishment of a new public support thrust in extension education. Such a thrust is needed particularly at the specialist and program development level which is a logical role for increased federal support and leadership.

Trends in Level of Support and Related Issues

In the 10 years from 1966 through 1975, the level of support for agricultural research and extension programs increased 215 percent in current dollars and by 30 percent in terms of constant dollars (Table 1). During this time period, research and extension resources increased at nearly the same rate.

From 1975 through 1982, total expenditures on research and extension increased 87 percent in terms of current dollars and 9 percent in terms of constant dollars.

Research-Extension Balance

From 1966 through 1975, federal support for extension increased considerably more than federal support for research. However, since 1975, research expenditures have increased somewhat more than extension expenditures. Increased support for agricultural research relative to extension has been particularly unbalanced when the surge of private sector investment in agricultural research is considered. This increased emphasis on

Table 1. Trends in Agricultural Research and Extension Funding by Source, User, and Selected Years.

Year	Research					Extension			Total Extension and Research
	Total Research	USDA	State Agricultural Experiment Stations			State Agricultural Extension Service			
			Total	Federal	State	Private	Total Extension	Federal	State and County Appropriations	
	millions of current dollars									
1966	359	153	206	79	118	9	201	75	126	560
1975	755	266	489	135	331	23	448	179	269	1,203
1982	1,394	469	925	268	563	94	854	315	539	2,248
	millions of constant dollars									
1966	363	155	208	80	119	9	204	76	128	567
1975	463	163	300	83	203	14	274	110	164	737
1982	497	167	330	95	201	34	304	112	192	801

Source: *Inventory of Agricultural Research*, CSRS/USDA (Washington, D.C., 1982), Extension Service, USDA. and *United States Food and Agricultural Research System*, OTA, (Washington, D.C., December 1981).

research likely reflects:

- a higher level of sensitivity to the needs for high priority biotechnology research;
- the potential for major breakthroughs in productivity;
- a reaction to concerns about the availability of an ample supply of food;
- a desire to maintain competitiveness in international trade; and
- the higher costs associated with biotechnology research which has been used to justify higher appropriations.

In a time of tight budget constraints, policymakers (particularly at the federal level) have apparently made a decision that research had a higher priority than extension. Longer-run questions, however, exist regarding the need to maintain a balance between research and extension activities.[7]

Research and extension are part of a complex agricultural system designed to discover, adopt, evaluate, and (where favorable) facilitate technology transfer to farmers and ranchers. One part of the system is as important or critical to its effectiveness in accomplishing this mission as the other.

The biotechnology era presents at least as many and probably more challenges for extension as it does for research. Many of the technologies that are on the horizon are exceedingly complex and foreign to many extension staff. In the foreseeable future, embryo transplant technology may be as important in dairy as artificial insemination has been over the

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[7] It is interesting to note that the relative increase in emphasis on research began during the Carter-Bergland administration. Previously the Nixon-Ford-Butz administration had put relatively greater emphasis on extension programs, while the Kennedy-Johnson-Freeman administration had favored research. The impacts of these shifts in emphasis in terms of productivity have not been adequately studied.

past three decades; growth regulators will increasingly be applied in minute quantities to plants to increase productivity; and new strains of genetically engineered plants and animals will be entering commercial production channels. *Extensive staff training and development will be required at both the specialist and county levels for extension to play an effective role in technology transfer during the bio and information technology era. Without such training, extension will play an increasingly less important role in production agriculture. Technology transfer will occur less efficiently with more structural impacts--larger farms will benefit at the expense of smaller farms.*

Another important effect of the research-extension imbalance in emphasis is to attract the best scientists into research rather than extension. While the public sector agricultural research community is experiencing increased difficulty competing with private sector firms for the services of qualified scientists, extension is having even more difficulty competing with both interests.[8] At the specialist level, extension draws on the same pool of Ph.D. trained scientists as does research. With research receiving increased emphasis, it is able to more effectively compete for the services of the top scientists.[9] Over time, unless corrected, *the result will be a lower quality extension staff.* The same principle applies at the county level where extension must likewise compete for its professional staff with both public and private sector employment alternatives. With relatively less extension support, the best county and area extension

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[8]There is a concurrent concern that the best research and extension scientists are being attracted into private sector managerial jobs.

[9]One method by which extension might have adjusted to this competition is to reduce the number of staff and concentrate more resources around a smaller number of highly qualified staff. Extension has not, as a general rule employed this strategy.

staff will be attracted to the private sector or to other better endowed agencies in the public sector. *These effects are already occurring.* They are occurring at a time when extension is being called upon to transfer a larger quantity of increasingly complex technology developed by biotechnology research.

Federal-State Balance

The states have been picking up a larger share of the cost of the agricultural research and extension system. From 1966 through 1975, federal support for research and extension declined as a proportion of the total, from 55 to 48 percent. In 1982 the federal share was 47 percent.

This trend is consistent with the philosophy of a reduced overall federal role. *However, it is inconsistent with the role of U.S. agriculture nationally in terms of maintaining stable prices, contributing to a favorable balance of trade, and meeting world food needs.* These are important national goals that signal a higher level of federal involvement and support.

During the period 1975 through 1982, most of the relative reduction in federal support has been in extension appropriations. While federal support for research increased by 7 percent (constant dollars), extension support increased by less than 2 percent (Table 1). State and county support for extension, on the other hand, increased by 17 percent. The federal share of extension support, thereby, fell from 40 percent, where it had been since the early 1950s, to 37 percent. Appropriations for extension in 1984 suggest a further drop in its share of federal support.

The rationale for reduced federal support for extension relative to research is unclear. While education has traditionally been viewed as a state and local community function, extension was formed on the principle of a federal-state-county partnership. The ability and willingness of

state and county governments to adequately support extension in the face of reduced federal support is questionable.[10] Clearly, if the biotechnology era justified higher levels of support for agricultural research, it also justified higher levels of support for agricultural extension--particularly with increased private sector commitment to agricultural research.

Research and Extension Professional Staff

Despite increases in real appropriations for agricultural research, the number of professional research staff has declined. This decline results from the continuously increasing cost of supporting a research scientist. These higher costs result primarily from increased expenditures on research equipment and materials. Even larger cost increases can be anticipated in the future as agricultural research progresses into the biotechnology era and as the demands of the private sector for newly trained scientists continue to accelerate.

Extension experienced an 11 percent increase in the numbers of professional staff from 1966 to 1975, and a subsequent 6 percent decline through 1984 (Table 2). Nearly all of this decline was in the specialist staff which experienced a 15 percent decline in numbers. This reduction in specialist numbers is particularly alarming since the specialist staff has the highest level of training and is the best equipped to educate both county agents and farmers on evolving agricultural technologies.

The disproportionate reduction in the number of specialist staff is

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[10] Interestingly, the 1977 farm bill contained authorization for the USDA to be the lead agency in university education programs related to agriculture. While there was a transfer of staff and offices from the Department of Education to USDA, *this initiative has received very limited USDA support and is essentially dead.*

Table 2. Trends in Numbers of Extension Professional Staff, Selected Years.

Year	Extension		
	Total	Specialist	County
1966	14,092	3,641	10,451
1975	15,581	4,224	11,357
1984	14,721	3,581	11,140

Source: Extension Service, USDA.

probably best explained by budget considerations and the lack of direct state control over county staff. As budgets tighten, considerably more funds are made available to the state director when a specialist position is eliminated or not filled. In addition, competition for specialist staff has become increasingly keen. *For extension program administrators, compared with reducing the number of county staff the avenue of least resistance is reduction in force at the specialist level--precisely what has occurred. Therefore, while the need is for an increased emphasis on specialist staff, just the opposite is occurring. In fact, one can forcefully argue that in the biotechnology era, without substantially increased emphasis upon county agent development, the specialist will have an ever increasing and comparative advantage in educating farmers. The model for cooperative education could shift from county agent-to-farmer education to specialist-to-farmer education. This is probably already happening and has the potential for substantially changing the structure and role of extension. Without substantially increased state and/or federal support for extension, counties will need to pick up a larger proportion of its costs or the counties' impact and effectiveness in their educational role will gradually erode.*

An alternative strategy for extension to keep pace with the bio and information technology revolution involves an intense, continuing program of staff development at the county level designed to provide county agents state-of-the-art research findings and related information. A decision to emphasize this strategy is based upon the premise that the strength of extension lies in the county agent. Historically, the county agent has been one of the best educated persons in the county. Questions are increasingly arising as to whether this era is gone.

Christenson and Wagner put the issue in the following very cogent terms:

> If county staff are not providing relevant and timely information, if they do not have access to innovative ideas, if they are not seen as outstanding educators in the county, they will not have the trust and respect of the people. County staff who are seen as just another information disseminator who hands out pamphlets, gives advice on fertilizing lawns and gardens, and holds meetings for "expert" speakers from the state university, may not survive in an information society (p. 12).

This is not to contend that all county agents are out-of-date. Many continue to carry out state-of-the-art programs. However, as the rate of technological change continues to accelerate, it will not only become increasingly difficult to keep up, but research results will become more complex.

Such observations on the problems of keeping up with the rate of technological change are not limited to county agents. Many researchers will also find their knowledge level bypassed (antiquated) by biotechnology; specialists equally will need to retool. However, the cost of retooling specialists will be less than that of retooling county agents. This is the case because there are fewer specialists and they have closer day-to-day contact with research.

Fund Allocation

The funds that land-grant universities receive from the federal government can be allocated either on the basis of competitive grants or formulas. Historically about two-thirds of the funds have been allocated to the states by formulas. While there are formula differences between research and extension, the principal factor in both formulas is rural population and farm numbers. As a result, states having a larger rural population and greater farm numbers receive more formula funds.

The specifics of the formula have been the subject of considerable

debate. Large rural population and farm numbers in the Southeast do not correspond with the quantity or value of production. Midwestern and western states feel that formula funds ought to be allocated on the basis of the value of commodities produced. Senator Lugar (Indiana) has become a champion of debate to change the formula (GAO).

Since agricultural research deals more with the products of agriculture than with population, Midwest advocates suggest that inequities result from research funds being allocated on the basis of population. Current formula funding procedures have tended to promote regional crops such as cotton, tobacco, and peanuts as opposed to wheat, corn, soybeans, milk, beef, hogs. Yet, those states that produce the majority of the wheat, corn, soybeans, milk, beef, hogs, fruits, and vegetables have been more competitive in achieving competitive research grants. In some instances, strong state research support has compensated for less federal support.

A change to a product-value-based formula would accelerate the trend toward increased centralization of research in the major agricultural states such as California, Iowa, and Indiana. It can also be argued that the effect would be to shift the allocation of research resources in the direction of middle-size and larger scale farms. However, questions exist regarding whether the size distribution of the clientele being served by research and extension is any different in those southern states that receive a larger proportion of formula funds just because of a larger number of smaller farmers. Maybe the needs of small farmers are not being served in the South any better than in the rest of the country.

In extension, the case for a population based formula appears to be stronger than in research. Education deals more with people than with the

value of products. However, even here the urgency of education can be argued to be product-value-based. That is, education is more urgent where more products are produced. In addition, as in research, questions arise as to whether extension is effectively serving the educational needs of farmers having smaller scale operations.

Competitive grants are a much discussed method of allocating USDA agricultural research funds. Prior to 1970, federal contracts and grants generally represented about 10 percent of the USDA funds going to the state agricultural experiment stations and only about 2 percent of total experiment station funds. However, the world food crisis and biotechnology created greatly increased interest in grants. By 1982, contracts and grants had increased to 16 percent of experiment station funding.

In 1977, Congress authorized a special competitive research grants program primarily to support basic research in food and agricultural science. The competitive grants program was available to any research institution--land-grant or not. In 1982, the experiment station received only 38 percent of competitive grant appropriations, accounting for less than 1 percent of experiment station funds. The land-grant universities accepted the grants concept only on the condition that grants not displace formula fund appropriations. At least partially because of land-grant resistance to formula fund reductions, the competitive grants program has received a low level of appropriations.

While the competitive grants are made on the basis of a peer review system, basic research scientists complain that the grants are generally so small that they cannot sustain even a middle-sized biotechnology research project. In 1982 the average size of grant was approximately $70,000 (CSRS, p. 15). The program is frequently referred to by biotech-

nology researchers as the "small grants program." The underlying reason for the small size of these grants probably lies in political pressure on USDA research administrators to distribute the grants geographically among the states.

For many years, extension has used savings from Federal administration funds plus approximately $500,000 in so-called "special needs" funds for allocation to the states in the form of competitive grants to support, among other priorities, the development and testing of innovative concepts of extension education. This important, highly successful, albeit informal, counterpart of the competitive research grants program has been severely restricted since 1978--ironically about the same time as the research grants program was initiated.

The reasons for this restriction lie in the interaction of such factors as reductions in federal administration funds; the subversion of extension funds to support a vast experiment to coordinate research and extension at the federal level; a congressionally mandated evaluation project; and the subsequent emphasis on increased on-going evaluation which had to be absorbed out of existing funds.

As indicated previously, one of the unique features of the extension special grants program was that the projects supported by it were frequently regional or national in scope, thus facilitating the production of educational programs that could be replicated and applied on a multi-state basis. Since the restriction of this program, innovative extension program development has been severely curtailed--particularly programs having a regional or national focus. Individual states have not, and probably cannot, fill this void. Several recent attempts to provide funds for these purposes as a designated item in the federal extension budget have

been unsuccessful.

Nonland-Grant Universities' Interaction with Land-Grant Universities

The world food crisis and biotechnology era have fostered increased nonland-grant interest in agricultural research. This interest was further heightened by the establishment of the competitive grants program in the 1977 farm bill. Experience indicates that the nonland-grant universities are fully competitive with the land-grants in receiving these funds. However, competitive grants have not been expanded sufficiently to significantly augment most nonland-grant agricultural research programs.

Increased funding for human research in the biotechnology area holds the potential for rapid technology transfer of medical discoveries to agriculture at a relatively low cost. Potential also exists for fortifying existing nonland-grant basic research in photosynthesis, plant embryology, genetics, and animal physiology. This will, however, require significant increases in funding beyond current levels as well as a movement away from the "small grants" philosophy discussed previously.

One of the factors hindering the contribution of the nonland-grant universities to discoveries in agriculture is the traditional competitive relationships with land-grant universities that have existed within states. With increasingly limited funding, competition for the division of appropriated funds, and the establishment of new educational programs has become increasingly intense. Over time, substantial conflicts have developed over the favored position of land-grant universities in having access to formula funds. Such conflicts even exist within land-grant universities between experiment station related agriculture departments and academic departments having no ties to the experiment stations--such as biology departments.

Such conflicts are difficult to overcome. Danger exists that in attempting to "force" cooperation, policymakers could destroy productive elements of the existing system that has served agriculture well. Yet constant pressure to obtain a higher level of cooperation would appear to be warranted. *Perhaps the most effective means of applying such pressure would involve the development of programs that provide financial rewards for cooperative land-grant, nonland-grant research programs.*

Property Rights, Exclusivity, and the Land-Grant Universities' Social Contract

Land-grant universities were created to serve the public. The agricultural component of the land-grant universities has unique responsibilities to conduct and extend the results of research for the public benefit. Traditionally, those research results have been readily and freely available to the public--having no private property or exclusivity rights attached to them. Research results that were to be held in confidence or had private property rights attached to them were frowned upon. *Policy changes that have occurred over the past 15 years hold the potential for substantially changing this traditional ready and free access concept of land-grant university research. Some changes have already occurred; others have the potential for occurring very rapidly. In other words, changes in the rules may have also changed the very concept of the land-grant system!*

Questions of how the land-grant universities might adjust to the new concept of research property rights and the related opportunities for increased private sector funding have been the subject of extensive study. However, the impact on the unique nature or "social contract" of the land-grant system has received little attention. A discussion of both dimensions follows. This discussion is important because it has a potentially profound effect on the land-grant system and its relation to the public.

The Development of Discovery Property Rights

Policy changes regarding property rights in agricultural research had their origin in the enactment of the Plant Variety Protection Act of 1970. Previously patent protection in plants was limited to asexually reproduced material--mainly orchard fruits and ornamental flowers. The Plant Variety Protection Act provides that a breeder of a new, stable, and uniform variety of sexually reproduced plants can restrain other seedsmen from reproducing and selling that variety for 17 years.

Of possibly greater significance was the 1980 landmark U.S. Supreme Court decision, *Diamond vs. Chakrabarty,* which held that the inventor of a new micro-organism, whose invention otherwise met the legal requirements for obtaining a patent, could not be denied a patent solely because it was alive. *This decision opened the door for patenting of potentially all new products of the biotechnology era.*

Since the passage of the Plant Variety Protection Act and the *Chakrabarty* decision, private sector interest in agricultural research has mushroomed. OTA, for example, found that in 1983, there were 61 companies pursuing applications of biotechnology in animal agriculture and 52 companies applying biotechnology to plants. The companies involved range from established agricultural chemical suppliers such as Monsanto, DuPont, Dow, Eli Lilly, and American Cyanamid to new biotechnology firms such as Genentech, Biotechnica International, MGI, and Genex.

Most of these firms have developed their own in-house research capability employing molecular biologists, biochemists, geneticists, plant breeders, and veterinarians. While past emphasis in plant and animal science was on selection and breeding for specific desired traits, now the emphasis has changed to *understanding the factors that control the genetic traits*

and overtly changing them. Progress is already being made with growth hormones, vaccines, and herbicide resistant varieties. Several genetically engineered products are very close to being marketed commercially.

Relationships are also developing between many of these firms and universities. For example, Monsanto has a 5 year $23.5 million contract with Washington University under which individual research projects are conducted. At Stanford University, five corporate sponsors (General Foods, Koopers Co., Inc., Bendix Corp., Mead Corp., and McLoren Power and Paper Co.) contributed $2.5 million to form the for-profit Engenics and the not-for-profit Center for Biotechnology Research.

Such relationships are not limited to private universities. Michigan State University (a land-grant) created Neogen to seek venture capital for limited partnerships to develop and market innovations arising out of research. The formation of Neogen points up a significant problem being encountered by the universities in the biotechnology era. Neogen was formed, in part, for the purpose of retaining faculty members who are getting offers from biotechnology companies. In Neogen, faculty members are allowed to develop their entrepreneurial talent and the associated financial rewards, while remaining at the university.

The formation of Neogen reflects the reality that biotechnology development is resulting in or has the potential to result in a substantial drain on university basic and applied research talent. If leading faculty members are not overtly hired away from universities, they may form their own companies or become consultants. The establishment of biotechnology property rights has substantially heightened scientists' interest in private sector employment opportunities. In the process, questions have arisen over who maintains the property right--the university, the

private firm, or the scientist.

In the Washington University-Monsanto case, the University retains the patent rights while Monsanto has exclusive licensing rights. In Engenics, Stanford likewise gets the patent rights while the Center and the six corporate sponsors receive the royalty-bearing licenses. Neogen will buy patent rights from Michigan State University while the inventor will get a 15 percent royalty or a stock option in Neogen.

Land-Grant University Adjustments

It does not take much imagination to recognize the potentially profound implications of such developments on the land-grant university system. While previously treating government-business ties at arms-length, such private sector arrangements integrate business into the university fabric. Questions develop over who controls the university research agenda, the allegiance of scientists to their university employer, the willingness of scientists to discuss research discoveries having a potentially patentable product associated with them, and potential favoritism shown particular companies by the university because of their research ties.

This controversy has caused the land-grant Agricultural Experiment Station Committee on Policy (ESCOP) to publically express its concerns and develop guidelines to deal with these biotechnology issues. The statement of concerns includes:

1. As publicly supported institutions, the SAES (State Agricultural Experiment Stations) will need to assure that industrial relationships generate an end result in the interest of the general public. This end result should reward the industrial investor but avoid placing such an investor in an unwarranted position of financial advantage through privileged use of information or technology partly derived from research using public funds; neither should a curtailment of new information to the public occur.

2. The SAES are greatly concerned about the curtailment of communication on early research results and about the constraints on sharing of germplasm emerging due to concerns on the part of scientists and institutions for protecting potentially patentable research results. Industry sponsorship of this kind of research tends to exaggerate this problem.

3. There is general concern in the academic community about the drain of scientific manpower from the universities to industry. The ability to continue to conduct basic research in an academic environment and the concurrent interdependent ability to continue educating scientists are key issues.

4. There is concern that individual scientists may place themselves in positions of compromise or conflict of interest as they establish personal relationships with industry as contractors, consultants, or institutional officers.

5. There is concern on the part of both scientists and the SAES that through industrial sponsorship of research, there may be introduced an undesirable level of direction of effort by industry. (ESCOP, p.4)

Out of these concerns ESCOP developed the following interim policy guidelines:

1. *Maintain SAES management control of research: ...Consensus:* SAES should retain the ability to manage research programs, and control the direction of new investigations, regardless of the source of support, including situations in which one or several firms may sponsor research at several institutions.

2. *Strong basic research and graduate education capability: ...Consensus:* SAES should maintain and expand the basic research capability in genetic engineering and related areas within the domain of publicly supported institutions.

3. *Faculty-industry relationships: ...Consensus:* Scientists should maintain close communication with institutional administrators in the development of relationships and commitments with the commercial sector. Institutional guidelines should be developed which assist the scientists in avoiding institutional or personal conflicts of interest.

4. *Publication and communication: ...Consensus:* The ability to publish and exchange information is essential and must be secured in agreements. In some instances, publications or information exchange may need to be temporarily delayed to allow time for an institution or sponsor to assure adequate patent protection. The final decision to defer or modify a publication should reside with the public institution.

5. *Trade secrets and confidential information: ...Consensus:* Protection

of "trade secrets" or "confidential information" for more than a very limited period should be avoided by public institutions. Advance review by a private sponsor, to avoid premature release of information, may be advisable but should not become a mechanism to "shelve" useful information or unpatentable technology.

6. *Patent rights and premature disclosure: ...Consensus:* SAES should retain the right to participate in the decisions related to the disposition of intellectual and real property and patent rights resulting from research. Retained ownership of patents by the SAES is preferred. In any agreement, the SAES should retain the right to use discoveries and inventions from SAES research to extend and enhance public research and education. The need of private sponsors to obtain a return on investment must be recognized, and agreements may provide for special licenses for patents originating from sponsored research.

7. *Biosafety of recombinant DNA: ...Consensus:* SAES must retain responsibility for review and decisions in the release or distribution of laboratory research products, although some research may be supported by outside sponsors.

8. *Grants and income earnings: ...Consensus:* Extending knowledge and developing new technology while serving the public interest should be the prime motivations in agreements between SAES and the private sector. Royalty income from discoveries originating under such agreements should be recognized as a secondary consideration.

9. *Licensing responsibilities and performance expectations: ...Consensus:* SAES should assure that "due diligence" clauses are included in contracts to assure that new technology is not shelved and the public interest is served while private investment in commercialization is respected. Assignments or rights or licensing of patents for commercial use should be considered separately from contractual definition of research to be conducted. Initial or developmental processes and pervasive technology ultimately leading to improved biological materials generally should not be assigned for sole use by a sponsoring firm.

10. *Tax code implications: ...Consensus:* When sponsored research is motivated by certain interpretations of Tax Code Section 1235, exclusive licensing or co-ownership of patent rights is a preferred alternative for the institution, since the institution maintains a vested interest and some ownership of patent rights involving the scientist, the institution, and the firm may require unique documentation. Careful attention to these rights and relinquishments is suggested. (ESCOP, pp.7-10)

Impact on the Land-Grant Social Contract

Potential basic changes in the relationship between land-grant universities and the public are implied by these adjustments--although not explicitly discussed. The land-grant university system was established on a unique public service basis different from other universities. Its tradition has implied a social contract that makes its discoveries freely available to the public. That is the reason for the existence of its research and extension components as distinctly different from any other university segment.

The advent of patent rights, exclusive licensing, and private sector investment in public sector research have the potential for changing the distribution of benefits from land-grant research discoveries.[11] These changes warrant direct public discussion and consideration by policymakers. They occur for at least five reasons:

- By exclusive licensing or transfer of patent rights to private firms, the right to *use* discoveries is no longer freely available --even if information on the discovery itself is freely available.
- Certain individuals and/or firms are conferred the benefits of specific land-grant research to the potential detriment of others. Prior to the transfer of discovery rights, the benefits were available to anyone who adapts a land-grant discovery to commercial usage.
- The costs of the resulting discoveries are internalized in the price of the resulting product. The price the public pays for the product also includes any monopoly rents associated with the con-

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[11]Similar implications may also exist for ARS research to the extent that patent rights and exclusive licensing arrangements are created by ARS.

ferral of the rights. Society thus pays twice: once for the cost of the research and then again for its benefits. Without the conferral of property rights, rents are minimized by competition.

- Private sector-public sector inequities are virtually assured in any granting of research property rights to an individual firm. This occurs because with a relatively small private sector investment there is access to a much broader range of current and prior research.
- The existence of patent rights, trade secrets, and confidential information has as many potentially adverse implications for extension in terms of the increased burden for product testing, the potential lags in information, and the absence of research information that would have previously been readily available.

The argument does *not,* however, flow exclusively against the conferral of private sector property rights by the land-grants. There are three main counterbalancing arguments:

- With the conferral of private property rights and the associated private sector investment, the quantity of research discoveries may increase. Evenson, for example, found a sharp acceleration in private plant breeding programs after the 1970 Plant Variety Protection Act was enacted into law. Over 1,088 patent certificates were granted by February 1, 1983 (p. 9).
- Without land-grant university involvement in private sector funded research, the universities may not be able to retain the top quality scientists needed to conduct agricultural research that is on the frontiers of knowledge. In the process, the agricultural research, extension, and teaching programs would all suffer.

- Patent monopoly rights may be necessary to attract the capital investment needed to translate land-grant university scientific advances into commercial reality. Without such proprietary protection, new discoveries may not be able to compete for resources to develop marketable products or technologies. The public availability of such products could thereby be affected.

If policymakers desire that land-grant universities not confer property rights, it will be necessary for them to provide the level of funding whereby they can compete with other nonland-grant universities who confer such rights. That is a basic public policy decision--maybe the most basic decision since the land-grant system was created. Once the land-grant system starts down the road of actively competing for private sector grants and conferring licensing rights, there is no turning back.

Pricing Information Services

While seldom recognized, one of the most critical aspects of United States agricultural policy is that of information policy. Much of what USDA does is provide information and, thereby, reduce imperfections in knowledge. Until the 1970s, most agricultural information available to farmers had its origin in USDA. The Department gathered the information, interpreted it, and published it. Extension Service personnel at state and federal levels and private sector media made the information freely available to the public. The information covered a very broad range--technology developments, public policy changes, statistical data, economic trends, and price forecasts. USDA was respected for having the best information system in the world. In many respects, USDA had a monopoly on information that was freely available to anyone--small farmer or large agribusiness firm.

The information policy of USDA began to change in the 1970s. Tight federal budgets resulted in cutbacks in the quantity and quality of information at a time when, because of greater instability, more and better quality information was needed. New methods of communication made timely transfer of information to the producer possible. This could be accomplished in closed, often computerized systems where the benefits could be captured by the supplier. Larger farm units required information of a more specific nature, tailored to their operations. Information had captured a value, yielding private sector profit opportunities.

Without substantially increased appropriations, neither USDA nor the land-grant system could adequately respond to these new demands. Perhaps more significantly, private sector firms, seeing increased profit opportunities, did not encourage increased funding for information. In the process, they indirectly (some might argue directly) discouraged increased funding. Their philosophy was basically one of "give us (the private firms) the raw data and we (the private firms) will interpret it."

At a time when policy makers were seeking opportunities to transfer functions from the public to the private sector, it seemed quite logical to cut back on public sources of information. Since the information that was being collected by USDA had acquired greater value, it also seemed logical to begin charging for all (or nearly all) USDA publications.

Why not make the beneficiaries of information pay for it? The answer lies in the resulting distribution of costs and benefits from information. Increasing quantities of information are available only to those farmers and agribusiness firms who can afford to pay for it. Those who can afford to pay for it are the larger farm operations and agribusiness firms. Those who cannot afford to pay for it are the middle size and small farms

(mostly family farms) as well as the middle size and small agribusiness firms. Since information is a lifeline for success in today's agriculture, its absence accelerates the trend toward a more highly concentrated agriculture.

Could not middle size and smaller farmers continue to get information from the Extension Service? For many that was the only continuing reliable and consistent source of information. But even that source was curtailed by a USDA policy requiring state extension staff to pay for USDA publications. *Its own employees were required to pay for the information they had the responsibility for distributing! Many states did not have the funds to obtain reports that were vital to timely producer decisions. Such policy changes are difficult to either justify or excuse.*

This problem is by no means limited to the federal government. Many states have also been forced by budget constraints to charge for publications as well as for many of their educational programs. *Such policies aggrevate the comparative disadvantage of middle size family farms competing in agriculture.*

Distribution of Benefits and Structural Impacts

Technology is one of the driving forces behind structural change in agriculture. This point has perhaps been most clearly argued by Cochrane. He points out that the first adopters of new technology are the immediate beneficiaries in that their costs per unit of production are lowered. Their profits thus rise. The profits of those firms supplying the products of new technology also rise. In addition to reducing costs per unit of production, technology generally expands output. Also higher profits encourage the adopting farmers to expand output--even to the extent of increasing the scale of their farm operation. But as output expands,

prices decline. Later technology adopters thus realize less profit. In fact, those farmers who are the last to adopt new technologies may actually be forced to either adopt or get out of agriculture.

Two important lessons arise from this description of the process of technological change:

- Those farmers who are most aggressive in effectively adopting and applying new technologies are the most likely to survive. Their size or scale of operation, thereby, influences the structure of agriculture. Likewise, to the extent that research discoveries or extension programs favor certain size farmers, structure is impacted. White finds in an accompanying OTA paper that this impact is less than has sometimes been asserted (Hightower). These findings do not, however, negate the concern about the neutrality issue. The importance of technology in fostering structural change makes constant awareness and consideration of its potential impacts important in designing research and extension programs.
- The ultimate beneficiary of agricultural research and extension is the consumer. Larger supplies, lower food prices, and better quality have almost invariably been the main end result of research. This does not mean that research operates contrary to the interest of farmers. Research directly benefits the more progressive farmers. Research is critical to expanding markets for farm products and maintaining the competitiveness of U.S. agriculture internationally. Research overcomes the constant threat of new disease and other vagaries of nature.

These lessons present a difficult problem for policy makers and land-grant university administrators. While the returns on investments in

agricultural research and extension programs are high, their benefits are by no means uniformly distributed. While farmers and agribusiness firms are frequently described as the main clientele of the agricultural research and extension system, they are not the long-term beneficiaries. The benefits enjoyed by farmers and agribusiness firms are not uniformly distributed. The adverse effects of technology on farmers who fail to adopt, agribusiness firms who fail to obtain the property rights, or on farm laborers who are displaced may be dismissed as one of the costs of progress. They are, however, accentuated by policies that:

- Fail to provide sufficient resources and incentives to serve the research and extension needs of the full range of farmer and agribusiness clientele regardless of their ability to pay for those services.
- Fail to provide alternative retraining and employment opportunities for those who are displaced by the effects of technological change.
- Fail to take into consideration the unique nature of the social contract under which the land-grant university system was formed in designing a system of property rights for its discoveries.

In other words, the trend toward industrialization may continue--but the scales should not be tilted by public policy to speed up the process or assure the final conclusion.

Summary and Conclusions

To an important extent, U.S. agriculture has been very successful because of technological advance. In times of rapid technological change there are often suggestions to attempt to stop or even turn back the hands of time. Applied to the bio and information technology era, such a strategy would be counterproductive and unwise. Yet consideration of specific

changes in research and extension policy may be justified. The following areas have been identified as meriting consideration for policy changes.

- The social contract upon which the agricultural research and extension system was created needs to be reevaluated. This issue should not be left for resolution by the courts. Specific guidelines need to be developed which, while allowing the System to compete, protect the public interest and investment in the agricultural research and extension functions. Both the Congress and the USDA should have an interest in this type of policy development.
- It is sometimes suggested that increased private sector support for agricultural research signals less need for public support. While private sector support is complementary to public support, basic bio and information technology research is very costly. A reduced role for public research and extension would provide a slower rate of technological progress and a lower level of protection for the public health and welfare. In addition, there is a strong public interest in maintaining an agricultural research component in each state to serve the problem solving needs of its agriculture.
- Many agricultural problems are local or regional in scope. The applied nature of the System, having an Agricultural Experiment Station and Extension Service in each state, has provided a unique capacity to identify and solve local or regional problems. Reality suggests that only certain universities have sufficient resources to compete for private sector support in the bio and information technology era. The result is a confluence of forces that could create a dicotomy of "have and have not" universities. In the process, traditional extension-research interaction and feedback

mechanisms could thereby break down--particularly in states that are not in a position to command a major biotech component.

- The role of Extension is even more important than it has been in the past. New, more complex products require evaluation and explanation. In states where experiment stations have attracted substantial private sector support, the product testing function can most objectively be performed by extension. As a result, explicit authority needs to be provided for extension to have the flexibility to engage in applied research functions such as product testing and evaluation.
- While agricultural research is not inherently biased toward large scale farms, lags in adoption by smaller and moderate farms have the same effect. Unless special attention is given to technology generation and transfer to moderate-size farms, major structural changes could result--leading to the eventual demise of a decentralized moderate-size farm structure. To the extent that preservation of family farms is a policy objective, special funding for and emphasis upon the problems of technology generation and transfer to moderate size farms is warranted.
- While the agricultural research system has received the benefits of increased funding from both private and public sources, extension funding has not materially increased. As a result extension staff at the county and specialist levels are becoming caught up in a whirlwind of technological change. The result is a need for the injection of substantial staff development funding into the extension system.
- Basic organizational issues need to be addressed by the Extension

Service as it enters the bio and information technologies era. The premise upon which extension was developed was that of the research scientists conveying the knowledge of discoveries to the extension specialist who, in turn, supplies information to the county agent who teaches the farmer. Over time, this concept has gradually but persistently broken down as agricultural technology has become more complex, and insufficient resources have been devoted to staff development. As a result, more emphasis has been placed on direct specialist-to-farmer education. More specialists have been placed in the field to have closer proximity to their clientele, but at the cost of less contact with research scientists. As these changes have occurred, the role of the county agent has become increasingly uncertain. Appreciation for and utilization of county agents as educators and technology transfer agents has declined. As a result of these changes, a basic structural reevaluation of the organization of the extension function of the agricultural research system is needed. Such a reevaluation will inevitably need to tackle the politically sensitive issues of the role of the county, state, and federal components of the Extension Service.

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Background Paper No. 5

Agricultural Structure Impacts of Emerging Technologies

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Office of Technology Assessment
U.S. Congress

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OFFICE OF TECHNOLOGY ASSESSMENT

AGRICULTURAL STRUCTURE GROUP

AGRICULTURAL STRUCTURE AND NATURAL ENVIRONMENT AND RESOURCES WORKGROUP

NOVEMBER 15-16, 1984

INTRODUCTION AND PURPOSE

This doument is a report of the Agricultural Structure Group of the Agricultural Structure and National Environment and Resources Workgroup of the Office of Technology Assessment (OTA). An assessment of the impact of technology on the structure of agriculture, focusing primarily on the farm level, is the main focus of the Agricultural Structure Group. One early step in the process of conducting the assessment involved definition and probable adoption rates of specific technologies that will impact production agriculture by the year 2000 and beyond. This step resulted in the definition of some 28 technologies that will affect production and/or management of plant and animal agriculture in various ways.

A portion of the aggregate assessment involved a two-day workshop specifically oriented to analysis of the impact on farm structure of these previously defined technologies. This document reports the major findings of the Agricultural Structure Group (ASG). An overview of the

workshop's organization and the essence of the conclusions of this group is provided herein. The organization, assumptions, and procedures of the ASG are provided initially. In addition, a synopsis of the discussions is provided for each major topic addressed by the Group.

WORKSHOP ORGANIZATION

The focus of the two-day workshop was on the technologies in relation to farm structure. A major portion of the first day was devoted to a definition and explanation of the 28 previously defined technologies. The initial discussions of the Agricultural Structure Group involved the potential impact of these technologies on capital and labor at the farm level and on the structural elements of vertical coordination, market access, and barriers to entry. The second day's discussions were concerned with the distributional impacts of the technologies and the broad categories of public policies which may achieve a predetermined target structural change over time.

The assessment of distributional impacts were by broad category of technologies. The distributional impact discussion considered both rate of adoption and change in physical output by farm size. The focus was on the flow of impacts from various technologies to structure.

As a final item, the Agricultural Structure Group addressed the reverse flow -- from structure to technology development and adoption. Thus, the potential causality between various farm structures and the development and adoption of technology groups also was addressed by ASG.

PROCEDURES AND ASSUMPTIONS

The ASG was convened by co-chairmen, Thomas L. Sporleder and

Michael J. Phillips. The ASG discussion began after briefings by experts in each of the 28 technologies previously defined by OTA. Group discussion was unstructured except for some materials prepared for the ASG which provided an agenda of discussion topics. The Delphi procedure was used to focus the group in terms of arriving at consensus conclusions concerning potential impacts of technology on selected economic variables.

The assumptions made by ASG which apply throughout this assessment of technological impacts to the year 2000 are:

1) Economic variables such as tax policy, interest rates, inflation rates, and prices are held constant at 1984 levels.
2) Impacts of technology groups are assessed separately assuming that only one technology group exists and is 100 percent adopted in 1984. Thus, potential interaction effects among the technology groups were not assessed.
3) Capital and labor were defined broadly so that they were the only factor inputs in the production process. Capital was defined as all non-labor non-management resources including land while labor was defined to encompass both management and labor.
4) The focus was production agriculture -- farms and ranches. An important element of structure was defined as number and size of farm firms. Although the group recognized the importance of other levels in the commodity marketing and food distribution channel, the focus remained on the farm level for reasons of manageability.

TECHNOLOGY GROUPINGS

The 28 individual technologies previously defined by the OTA Assessment were grouped into 3 broad categories for animal agriculture and 4 broad categories for plant agriculture, Table 1. These individual technologies were judged by the Agricultural Structure Group as sufficiently similar in impact on market structure to permit assessment for the several technologies within the group rather than each individual technology.

The biological group essentially consists of technologies that use living organisms or their isolated components for manipulating plant or animal production. The mechanical group encompasses technologies developing in machinery used to produce and/or harvest crop or animal production. The information group includes the technologies of sensors, controllers, and actuators along with broad developments in computer technology applicable to the collection and analysis of information for producer level management decisions.

The management techniques group includes individual technologies which assist in a more optimal long-term combination of inputs at the producer level. The management techniques group consists of water and soil-water-plant relations, soil erosion, soil productivity and tillage, multiple cropping, organic farming, and land management. These technologies were grouped together under this heading because each involves cultural or management practices. Whereas the other categories apply to both crop and livestock production, the ASG felt that the technologies within the management techniques group apply only to crop production.

Table 1. *Groups of Technologies Analyzed by Agricultural Structure Group, By Animals and plants.*

Technology Group	Technologies Included
Animal	
Biological	Genetic Engineering, Animal Reproduction, Regulation of Growth and Development, Animal Nutrition, Disease and Pest Control
Mechanical	Environment of Animals, Animal Behavior, Crop Residues, Animal Waste Use, Robotics
Information	Monitoring and Controlling, Communication and Information, Telecommunication
Plant	
Biological	Genetic Engineering, Enhancement of Photosynthetic Efficiency, Plant Growth Regulators, Plant Disease and Nematode Control, Management of Insects and Mites, Weed Control, Biological Nitrogen Fixation
Mechanical	Robotics, Engines and Fuels, Crop Separation-Cleaning-Processing
Information	Monitoring and Controlling, Communication and Information, Telecommunications
Management Techniques	Water and Soil-Water-Plant Relations, Soil Erosion, Soil Productivity and Tillage, Multiple Cropping, Organic Farming, Land Management

ASSESSMENT OF TECHNOLOGY GROUPS RELATIVE TO STRUCTURE

There are a number of structural dimensions that could be assessed in terms of the impact of technology. The elements chosen were capital and labor, vertical coordination, market access, barriers to entry, and regional impacts. These elements are not necessarily the only relevant ones for judging the impact of various technologies. However, in the interest of manageability in terms of scope and time, these were judged most important.

Capital was viewed broadly as all non-labor and non-management inputs including land while labor was viewed broadly as both management and labor. Vertical coordination was defined as quality, quantity, and timing coordination across producer-first handler markets. Control primarily refers to the ability of producers to exercise authority over production and marketing decisions. Market access refers to whether producers have access to most or all buyers at a particular stage of the marketing channel. Barriers to entry were defined as the inability, for whatever reason, of new firms to enter a particular industry.

These structural elements are the common ones normally viewed as important in agricultural commodity markets. For any of the structural elements, it is difficult to judge or precisely measure the magnitude of impact from various technologies. The direction of impact (positive or negative) often is easier to judge than magnitude. The procedure used by ASG participants was to discuss direction of impact, then use the Delphi process to judge magnitude of impact within some predetermined range (e.g. 0-10 percent, 10-20 percent, etc).

Capital and Labor

One impact of technology can be on the capital and labor used in production of either animals or crops. The absolute and relative change induced by technology in capital and labor was addressed by the Agricultural Structure Group, Table 2. An initial discussion assessed the differences in impact expected among the broad technology groups on various structural elements. The Delphi procedure then was used to gain a consensus magnitude of impact for each technology group.

Biological Group

Several primary effects of technologies in this group in regard to capital were identified. The reproduction and genetic engineering technology was viewed as being adopted by farmers through purchasing a specialized service and in turn slightly reducing (<5%) both capital and labor necessary for a given size herd. An example is that a dramatic reduction in time spent checking a dairy herd for estrus is expected as a direct consequence of this technology, viewed as adopted through hiring a specialized service.

Growth hormone technology also was expected to slightly decrease both capital and labor inputs in animal production. Animal nutrition and disease control technologies were expected to slightly decrease or have no impact on capital and labor in the long-run.

Because both capital and labor are expected to decrease slightly as a result of these biological technologies, no significant change (that is, less than 5%) is expected in the capital - labor ratio. The ASG viewed capital as decreasing slightly less than labor, on the average, but this difference was not viewed as significant.

Table 2. *Potential Impact of Technology Groups on Capital and Labor at the Producer Level, Assuming Adoption, By Animals and Plants, Agricultural Structure Group.*

Area and Technology Group	Potential Additional Change Induced by Technology Group by Year 2000 in		
	Capital	Labor	Capital/Labor Ratio
Animal			
Biological Group	Slight Decrease (<5%)	Slight Decrease (<5%)	No Significant Change
Mechanical Group	Moderate Increase (5-10%)	Slight Decrease (<5%)	Moderate Increase (5-10%)
Information Group	Moderate Increase (5-10%)	Slight Increase (<5%)	Moderate Increase (5-10%)
Plant			
Biological Group	No Significant Change	Slight Decrease (<5%)	No Significant Change
Mechanical Group	Moderate Increase (5-10%)	Slight Increase (<5%)	Moderate Increase (5-10%)
Information Group	Moderate Increase (5-10%)	Slight Increase (<5%)	Moderate Increase (5-10%)
Management Techniques Group	Slight Increase (<5%)	Moderate Increase (5-10%)	No Significant Change

The biological group for crop production was composed of genetic engineering, the enhancement of photosynthetic efficiency, plant growth regulators, plant disease and nematode control, weed, insect and mite control, and biological nitrogen fixation. These technologies were viewed by ASG as having a long-run neutral impact on capital input at the farm level. The primary reason is that the majority of these technologies become available as new plants or seeds. Thus, the technology is imbedded into the factor input without a separate purchase of it. Potential price increases in plants or seeds were viewed as being offset by productivity gains.

A slight decrease in labor input is expected from the technologies in this group for plant agriculture. This was expected mostly from the potential for weed, insect and mite control technologies reducing some labor input into the production process. This also is the potential impact of plant disease and nematode control technologies.

The capital - labor ratio is not expected to change significantly as a result of the technologies in the biological group for crops. The decrease in labor anticipated from some technologies within the biological group is not expected to be important enough to change the capital - labor ratio significantly in the long-run.

Mechanical Group

This group for animal agriculture encompasses animal environment, animal behavior, crop residues and animal waste use, and labor-saving technologies for livestock production. The mechanical group for animals in terms of environment was viewed by ASG primarily as housing and lighting control for animals which may influence breeding and/or growth.

The other technologies within this group were viewed primarily as improvements in mechanical methods for crop residue or animal waste processing.

Almost by definition, this technology group is composed of technologies which require capital equipment expenditure if adopted. The ASG expected, as a result, a moderate increase (5-10%) in the amount of capital required due to these technologies.

As a consequence of these mechanical technologies, some slight decrease in labor is expected. The primary reason for this was the potential of the mechanical technologies to reduce stress on livestock, which in turn may reduce management input. The decrease in labor for livestock operations, however, is anticipated to be less than 5 percent in the long-run.

The capital - labor ratio, as a result of adopting the mechanical technologies group, is expected to increase moderately (5-10%)for livestock producers. This results from both a moderate increase in capital and a slight decrease in labor.

The mechanical technologies group for plant agriculture includes robotics, engines and fuels for various farm machinery, and crop separation - cleaning - processing techniques. As with this technology group for animal production, the ASG expected a moderate increase in capital input resulting from the adoption of these technologies. Cost of engines is expected to rise as a result of this technology. Engines are expected to be a higher horsepower for the same size. The major technologies in this group were expected to be capital intensive.

The potential for labor reduction from the technologies for crops

was expected to be similar to the impact for livestock. The expectation is for a slight decrease (<5%) in labor input attributable to this technology group.

The capital - labor ratio is expected to increase moderately (5-10%) as a result of the mechanical technologies for crops production. This is due primarily to increased engine costs and small labor reductions. The expectation for the capital - labor ratio for crop production due to this technology group is similar to that expected for livestock production.

Information Group

The technologies included in the informtion group were viewed as capital intensive, and the technologies within this group were expected to have a similar impact for crop and livestock producers. Actuators, sensors, and controllers all would require additional capital expenditures for production units such as feedlots, dairy barns, or crop fields. The consensus was that these technologies would require a moderate increase (5-10%) in capital for either crop or livestock operations.

Because the total amount of data and information available to managers would increase as a result of this technology, this would also cause a slight increase (<5%) in managerial time. The managerial input results from increased information which would be available to managers prior to decision-making. Since more information would be generated from the technology, managerial analysis time would increase. The ASG viewed this situation as similar for either livestock or crop operations.

The capital - labor ratio was viewed as increasing moderately (5-10%) as the net result from these technologies. No significant differences are anticipated between livestock and crop production as a result of information technologies. The capital - labor ratio is expected to increase primarily from an increase in capital equipment items used in production of either crops or livestock.

Management Techniques Group

The technologies included in this group are all aimed at management of resources in the production of crops. This is the only technology group which is unique to crop production. The technology group represents various management regimes useful in crop production.

The organic farming technology within this group was viewed essentially as a substitution from chemical factor inputs (such as fertilizer or insecticides) to mechanical factor inputs (more cultivation). The substitution of mechanical activity for chemical activity would lead to some capital expenditure decreases but some labor expenditure increases in crop production in the long run.

Other technology in this group was viewed as relatively more capital intensive -- such as soil erosion, tillage, and general land management. As a result, the net impact of this technology category on capital used in crop production is a slight increase (<5%).

Many of the technologies within this group are expected to require additional management input. Almost by definition of this group, adoption of the technologies is expected to demand greater management in the production process. As a result, labor encompassing management, is expected to increase moderately (5-10%).

The capital - labor ratio attributable to this technology group is not expected to change significantly. The increase in capital and the increase in labor are expected to be sufficiently similar so that no significant change is induced in the capital - labor ratio for crop production in the long term.

Vertical Coordination and Control

This structural element refers to quality, quantity and timing aspects across markets. The consideration in this area is that if technology induces tighter vertical coordination by an integrator it may simultaneously induce a shift in control over production from the farmer to the integrator. This, in turn, could impact on the number and size of farms in the long run. The poultry industry was discussed by ASG as an example of a commodity marketing channel which exhibits relatively tight vertical coordination, loss of producer control and a consequent shift to fewer but larger production units.

In general, the technologies were expected to allow more control over the end product characteristics. Examples include less fat per unit of lean in meat animals or a specific color characteristic in corn. This implies that more homogeniety within a type of product may result but more end products with engineered characteristics. This would mean some shift away from sorting or grading as a means to achieve greater homogeneity toward more control over the production process which would produce homogeneity during production.

An anticipated economic consequence of this increased control over production practices is contracting. Contracting allows husbandry practices or cultural practices to be monitored and controlled closely dur-

ing the production process. Controlled diversity would result from this arrangement. That is, greater process control would lead to uniform product differentiation.

The structural elements provide some indication of the potential for a technology group to induce a change in farm size and number over time. The directional impact of the technology groups on each selected structural element is summarized in Table 3. The table applies to both animal and plant agriculture across all technologies. The discussion in the text is by technology group.

Biological Group

The biological group of technologies is expected to encourage closer coordination in livestock production compared to the situation in 1984. The ASG believed that these technologies would encourage greater process control which would be manifest in more contract livestock production. One example discussed was swine producers contracting with meat packers where producers are paid for labor and facilities at a predetermined fixed rate.

Another example is the potential from these technologies for modifying milk at the cow rather than at the processing plant. This technology group holds promise for producing more highly unsaturated fats in milk. If such technology is adopted, it would require close coordination at producer-first handler markets and additional process control at the production level.

The expectation was for this technology to encourage closer coordination in crop production as well. However, even though the direction of impact was viewed similarly between livestock and crop production,

Table 3. *Potential Directional Impact of Technology Groups on Structural Elements at the Producer Level, By Animals and Plants, Agricultural Structure Group.*

Area and Technology Group	Potential Additional Direction of Impact Induced by Technology Group by Year 2000 in		
	Vertical Coordination and Control	Market Access	Barriers to Entry
Animal			
Biological Group	Closer Coordination Encouraged	Slight Reduction	No Significant Change
Mechanical Group	No Significant Change	No Significant Change	No Significant Change
Information Group	No Significant Change	Slight Increase	Slight to Definite Reduction
Plant			
Biological Group	Slight Encouragement of Closer Coordination	No Significant Change	No Significant Change
Mechanical Group	No Significant Change	No Significant Change	Slight Increase
Information Group	No Significant Change	Increase	No Significant Change
Management Techniques Group	No Significant Change	No Significant Change	Slight to Moderate Increase

the magnitude is expected to be relatively less for crops compared to livestock. Part of the reason is that relatively more process control in livestock than crops is expected from adopting the technologies.

Mechanical Group

No significant change in vertical coordination is expected from the technologies in the mechanical group for either crop or livestock production. The technology for this group essentially is embodied in capital equipment items such as tractors and other machinery. As a consequence, adoption and use of the technology is a decision made by individual production units with no real implication for vertical coordination or control.

Information Group

The technologies within the information group are not expected to have any significant impact on vertical coordination or control for either crop or livestock production. The situation for this technology group is similar to the mechanical group. Adoption and use of these technologies are decisions of individual farm and ranch managers.

One possible impact from the information technologies to vertical coordination was the potential for the technology to encourage more open markets for commodities, rather than contractual arrangements. The technology was viewed as having some potential for coordination across markets without integration. This impact would be attributable to better communication of buyer's needs to production level managers. This potential was viewed by ASG as slightly more important in livestock production than for crops.

Management Techniques Group

No significant change in vertical coordination or control is expected from the management techniques technologies. The technologies in this group are expected to be neutral in impact on vertical coordination and control, again mostly due to individual managers' decisions on adoption and use. Also, this technology group primarily reflects production decisions that are more likely to change quantity of output rather than quality.

Market Access

Market access as a structural element of agricultural marketing channels refers to sellers or potential sellers ability to gain access to buyers or potential buyers. The extent to which producers have a number of alternative buyers and/or marketing arrangements for their commodities is the essence of market access. If alternatives are few, market access is low. Foreclosure to participation is not necessary for market access to be low, but may be one reason for lack of market access.

Biological Group

The biological group is expected to slightly reduce market access for livestock producers in the long-run. This impact is expected because the biological technologies will allow targeting certain product characteristics to specialized end-use markets. This will narrow the range of alternatives for producers adopting the technology. Thus, foreclosure to other market segments is one impact expected from the technology.

The impact of the biological group on market access for crop production is expected to be neutral. Even though some potential for market segmentation by end-use characteristics is possible from this technology group, the ASG expected no significant change.

The discussion reflected the feeling that with today's technology of production, there were a number of possibilities for producing specialized crops or sorting commodities for particular end-use markets which is not being done. One example is sorting and grading soybeans on the basis of oil yield. Consensus was that, for storable commodities especially, the sorting may well occur after production, rather than through exercising process control during production. To the extent this happens, the technology group would have neglible impact on market access over time.

Mechanical Group

These technologies are not expected to have any significant impact long-term for either crop or livestock production. The technologies in this group are viewed as neutral on market access for reasons similar to those for the vertical coordination and control structural element.

Information Group

Some differences are expected between plant and animal agriculture from this technology group. The direction of impact from this technology group was the same for both areas-- to increase market access. The magnitude, however, is expected to be relatively more for crop producers.

This technology group encompasses increased information available

to managers for both production decisions and marketing decisions. The marketing information component is expected to be important for both but relatively more important to crop producers than livestock producers. As marketing information increases among buyers and sellers, improvement in market access is expected. If market information is asymmetrically held among buyers and sellers, the technology should result in more equality among buyers and sellers. The potential significance of this improvement is expected to be slightly greater for crops than for livestock.

Management Techniques Group

No significant change in market access is expected as a result of the technologies within the management techniques group for crops. Again, reasons are similar to those provided under the vertical coordination and control structural element.

Barriers to Entry

Barriers to entry refer to restricted ability of new firms, for whatever reason, to enter an industry. For example, use of specialized capital intensive and managerially sophisticated technologies for production within an industry can represent a barrier to new entrants in the long-run. Information asymmetry, or unequal access to information, or significant amounts of proprietary information within an industry, also conventionally is regarded as a discouragement to new entrants.

Biological Group

No significant impact on barriers to entry was expected from the biological technology group for either crop or livestock production.

This technology group may increase the level of sophistication and/or specialized knowledge necessary for production. However, the ASG believed that the expertise necessary would be available to nearly all production units. This was seen as available from firms specialized in providing the necessary expertise that may be required to adopt and use the biological technologies. Thus, impact on barriers to entry was viewed as neglible.

Mechanical Group

The mechanical technologies impact on barriers to entry in the long-term is expected to be no significant increase for livestock production but a slight increase for crop production. The reason for this difference is attributable to the expected differences in the relative importance of mechanical technologies in the two areas.

Crop production mechanical technologies are viewed as relatively more important and capital intensive per dollar of output than mechanical technologies for livestock. The capital intensive nature of this technology group for crops is expected to impose slightly increased barriers to entry in long-run production.

Information Group

Again, there were differences between crop and animal production in terms of barriers to entry from information group technologies. This technology group is not expected to significantly change barriers to entry in crop production. However, slight to definite reductions in barriers to entry in livestock production are expected from the information technologies.

The information technologies group holds the potential for significanatly increasing the amount of information on markets available to livestock producers without the necessity of large increases in capital expenditures to adopt the technology. In addition, monitoring and controlling devices are expected to be relatively more cost effective for livestock producers than for crop producers. This implied the potential for increased productivity with, perhaps, a lower quality of management. Both the production and marketing information technological impacts combine to encourage new entrants into livestock production--or reduce barriers to entry in the long-run.

Management Techniques Group

Some portions of this technology group are expected to be capital intensive. For example, land management strategies and multiple-cropping were considered as two specific technologies within the group which require expanded capital expenditures for adoption. The potential to create an additional barrier to entry from the technology group is through the capital intensive nature of the technology. If multiple cropping or land management practices were the norm for crop producers, the ASG anticipates that this would discourage new entrants into crop production in the long-run.

Regional Impacts

The Agricultural Structure Group also addressed potential regional shifts in production induced from the technologies, assuming they were adopted. The potential of regional shifts was seen as most likely in beef production from the biological technologies group. Some biological

technologies promise to increase beef cattle forage utilization from grazing.

This implies a potential significant long-term shift in production from the Midwest to the South and West. The potential for increasing the efficiency of converting pasture for beef cattle is likely to favor shifts in production away from the higher opportunity cost agricultural land of the Midwest.

Regional shifts in dairy were not expected on a comparable scale compared to beef production. The importance of feed concentrates and population centers to milk production are anticipated to nullify most of the impact of improved forage utilization.

A considerable amount of discussion was devoted to animal care and animal environment technologies. Some animal rights groups have targeted agriculture as their next objective-- particularly confinement feeding operations. To the extent that animal environment becomes a policy consideration, significant regional impacts were seen as a result. The result anticipated is a more geographically disperse, smaller size production unit.

Another consideration realted to the biological technology group in livestock is the objective of animal environment groups to stop whole animal experiments in favor of computer modelled biological experiments. This was viewed by the ASG as potentially slowing the stream of animal biological technology available between now and the year 2000. This also would change the direction of the perceived impact of the biological technologies on various structural elements in the opposite direction.

RELATIVE ADOPTION RATES BY SIZE

The rate of adoption by size of firm for each technology group was addressed. Adoption rates were estimated for the year 2000, assuming that firms would adopt at least one of the technologies within the group in some significant way, Table 4. Size categories used for farms were annual sales in 1984 dollars: 1) less than $20,000, 2) $20,000 to $99,999, 3) $100,000 to 499,999 and 4) $500,000 and over.

Relative adoption rates of biological technologies for both plant and animal agriculture are expected to be significantly higher by the year 2000 than for any of the other technologies, Table 4. This is especially true in the two smaller size categories of farms. About 40-50 percent of the smallest crop production units are expected to adopt at least one technology while 10-20 percent of the smallest animal production units are expected to adopt.

This perceived difference in adoption rates between crop and livestock producers is attributable to the form in which the technology will be available for adoption. Many biological technologies available to crop producers are expected to be embodied in seeds, fertilizers or other input items that normally would be purchased by crop producers. Many crop producers are expected to adopt some simple techniques and information technologies as a normal practice. This acocunts for the perception that these will be relatively more widely adopted.

Relative adoption by size is expected to be greatest for larger farms. Generally, 70 percent or more of the largest farms are expected to adopt some technologies from each technology group. This compares to only 40 percent for the second largest and about 10 percent for the

Table 4. *Percent Adoption Rate of At Least One Technology Within a Technology Group, By Size of Farm, Year 2000.*

Area and Technology Group	Adoption Rate Range, by Sales Size Category (1984 Constant Dollars)			
	Less than $20,000	$20,000-$99,999	$100,000-$499,999	$500,000 or more
	-- Percent --			
Animal				
Biological	10-20	30-40	60-70	80-90
Mechanical	0-10	10-20	40-50	70-80
Information	0-10	10-20	55-65	80-90
Plant				
Biological	40-50	60-70	85-95	90-100
Mechanical	0-10	10-20	40-50	70-80
Information	0-10	15-25	55-65	75-85
Management Techniques	10-20	30-40	55-65	70-80

smallest two categories. The economic advantages from the technologies are expected to accrue to early adopters, and a larger proportion of large farms are anticipated to be the early adoptors.

Among the largest production units, the ASG felt that biological technologies would be adopted by a relatively higher proportion of producers than mechanical technologies. This difference stems from mechanical technology adoption requiring more capital expenditures whereas the biological technologies were anticipated to be available from a service company on a fee basis. Thus, large firms and small may have these biological technologies more readily available to them.

RELATIVE EFFECTIVENESS OF POLICY IN ACHIEVING STRUCTURE

Policies Considered

The potential for achieving a particular size distribution of farms through various broad types of policy was assessed by the Agricultural Structure Group. Eight types of policy were defined regarding their potential use in changing relative size distributions of farms in the future.

The ASG considered the following policies: commodity, tax, credit, research and extension, trade, monetary, fiscal, environmental, and regulatory. The discussion focused on which of these policies might be most useful in achieving some public policy determined farm structure distribution (number and size of firms). As before, a Delphi procedure was used to rank the relative effectiveness of each of the major policy categories. Relative effectiveness of these policy categories were then assessed by the panel, Table 5.

Table 5. *Relative Effectiveness of Types of Policy in Attaining a Desired Specific Structure, Rank Order, Agricultural Structure Group*

Policy Type by Rank Order, Most to Least Effective
1. Commodity
2. Tax
3. Credit
4. Macro Policy-monetary and fiscal
5. Regulatory
6. Trade
7. Research and Extension
8. Environmental

Relative Effectiveness

Commodity policy and tax policy are expected to be most effective in achieving a particular size distribution in the future. That is, consensus was that specific policies under these two broad types could be designed that would either significantly decrease or increase the trend toward fewer but larger production units.

Credit and macroeconomic policy also are expected to be effective in changing the structure. Environmental policy and policies involving research and extension are expected to be the least effective in changing the size distribution of production units.

Commodty policy was viewed by ASG as the single most effective policy category for achieving some predetermined level of size and number of farm firms. For example, if a commodity policy were put in place which had a $10,000 limit on payments the effect would be to slow or stop the move toward larger farm firms. Similarly, if a commodity policy were put in place which had no payment limitation, this would encourage the trend toward larger size firms.

Also, even though commodity policies primarily impact on dairy and major crop producers, the ASG believed there could be aspects of commodity policy designed to encourage participation. Such items include differential support rates by size of farm. Smaller firms would have higher support levels, thereby encouraging broader participation across all farm sizes.

Tax policy was considered the second most effective policy category for changing the number and size of farm firms to some desired level. The major items discussed were investment tax credits or other tax items

which encourage capital to flow into or out of agriculture for tax shelter considerations. Treatment of capital gains, conversion of capital gains, and/or value-added taxes were considered as critical items that could influence size distributions.

Credit policies were considered as the third most influential in changing number and size of firms. Interest rates, availability of credit for agricultural production, capital rationing, and subsidized credit all were discussed as specific items in the credit policy category that would directly impact on movement over time toward larger size firms.

Other policy categories were expected to have less impact than commodity, tax, or credit policy. Macroeconomic policy was expected to be of some influence, followed by regulatory, trade, research and extension, and environmental policies. These last four policy categories were not considered to have as direct an impact on structure as the first four policy categories.

STRUCTURAL IMPACT ON TECHNOLOGY

The majority of this analysis is directed toward technological impacts on structure. Another area considered by ASG was the potential causality of a particular farm structure on the direction and magnitude of development and adoption of technology. The notion is that structure and technology are simultaneously related through time. Not only will technology influence structure but structure will influence technology. As a final item, the panel considered the potential relationship from structure to the various technology groups.

The assessment of structure on technology considered each previously defined technology group separately for both animal and plant agriculture. The question addressed by ASG was the direction and magnitude of impact that a bimodal farm structure would have on the development and adoption of the technology groups. The impact is relative to the structure which currently exists. The bimodal distribution assumed to exist for this portion of the assessment was a total of 1.1 million farms, 528 thousand in an annual sales category of less than $20,000, 143 thousand in a category between $20,000 and $99,999, 120 thousand in a category between $100,000 and $499,999, and 309 thousand in an category above $500,000. This bimodal distribution has 48 percent of all farms in the smallest category and 28 percent of all farms in the largest category. Thus, these two categories account for 76 percent of all farms.

As before, the Delphi technique was employed to gain a consensus on the influence of structure. Overall, the influence of structure on the development and adoption of technology was substantial, Table 6. A bimodal structure was viewed as having moderate or large increases on development and adoption for each of the technologies for both animals and plants. This was primarily because of the proportion of total farms in the largest size category (28 percent in the bimodal distribution compared to less than 2 percent actual in 1982).

Table 6. *Potential Directional Impact of Farm Structure on Development and Adoption of Technology Groups, By Animals and Plants, Agricultural Structure Group.*

Area and Technology Group	Potential Direction of Impact Induced by Bimodal Structure by Year 2000
Animal	
Biological Group	Moderate Increase
Mechanical Group	Moderate to Large Increase
Information Group	Moderate to Large Increase
Plant	
Biological Group	Moderate Increase
Mechanical Group	Moderate Increase
Information Group	Moderate to Large Increase
Management Techniques	Large Increase

The perception was that large farmers have relatively greater adoption rates and a significant proportion of large farms also would encourage development of various technologies beyond what would otherwise be developed. Differences among technology groups were slight. The greatest impact of structure on development and adoption was perceived to be on the management techniques group for crop producers. Larger crop farms would tend to adopt technologies such as multiple cropping, soil erosion or tillage practices, or soil-water-plant management techniques considerably quicker than smaller farms.

SUMMARY AND CONCLUSIONS

All technology groups are expected to have considerable economic impact on farm structure by the year 2000. The assessment by the Agricultural Structure Group indicates a relatively more important effect from biological technologies than from the other technology groups. An historical perspective on mechanical technologies is that they have been vitally important in shaping the livestock and plant production structure that exists in 1984. In general, while mechanical technologies are anticipated to be important, they are not expected to have as important an impact on future structure as biological technologies.

Capital and Labor

For animal production, both the information and mechanical groups are expected to moderately increase capital, with a slight decrease in capital induced by the biological group. Both biological and mechanical groups are expected to induce slight decreases in labor, with a slight increase induced by information technologies. No significant change is expected in relative capital and labor from the biological group. Moderate increases in capital intensity (increase in capital - labor ratio) are expected from both the mechanical and information groups.

For plant production, moderate increases in absolute capital are expected from both the mechanical and information groups, a slight increase from the management techniques group, and no significant change from the biological group. In terms of absolute labor and management, all but the biological group are expected to increase labor slightly to moderately. The only labor decreasing technology is expected to be the biological group. No significant change in the relative amounts of capital and labor are expected from the biological or management techniques groups. The mechanical and information groups are expected to induce a moderate increase in capital relative to labor. None of the technologies are expected to induce a decrease in the capital-labor ratio.

Comparison of the technology groups between plant and animal production reveals that, in general, the technologies are expected to be similar in terms of impact on capital and labor. Neither the biological or management techniques groups are expected to induce any significant change in the capital - labor ratio for plant production. The biological group is not expected to change the capital-labor ratio while all

other techniques are expected to moderately increase this ratio long-term.

Other Structural Elements

The Agricultural Structure Group also assessed the potential direction of the marginal impact induced by the technology groups on selected structural elements. The structural elements were vertical coordination and control, market access, barriers to entry, and regional shifts. The biological group is expected to encourage closer vertical coordination (i.e. more contracting), with a slight reduction in market access as a consequence. This would subsequently encourage the trend toward fewer but larger farms.

In the opposite direction, the information group is expected to actually reduce barriers to entry and increase market access without any significant change on vertical coordination or control at the producer-first handler level. The mechanical group is expected to be neutral on all structural elements analyzed.

Expected impacts on these structural elements for plant production is similar to that expected for animal production. However, the impact of the biological group on crop agriculture is expected to be less than for animal agriculture. Less impact on vertical coordination and market access is expected from biological technologies for crops. The management techniques technologies, a group unique to crops, are not expected to change vertical coordination or market access but are expected to slightly to moderately increase barriers to entry in crop production in the long-run.

The potential for regional shifts from technology was seen as most

likely from the livestock biological technology group, particularly as they effect beef production. Biological technologies that increase the efficiency of beef cattle forage utilization may have an important regional dimension. The potential for increasing pasture conversion of beef cattle is likely to favor shifts in production away from higher opportunity cost agricultural land of the Midwest to the South and West.

Considerable attention was devoted to animal care and animal environment technologies relative to regional impacts. To the extent animal environment, especially confinement feeding operations, becomes a policy factor then significant regional shifts may occur. The result anticipated is a more geographically disperse and smaller size production units.

Relative Adoption Rates by Size

Relative adoption rates of biological technologies for both plant and animal agriculture are expected to be considerably higher by the year 2000 than for any other technology group. This is especially true for small farms.

Relative adoption rates of all technology groups are expected to be greatest for larger farms. Generally, 70 percent or more of the largest farms are expected to adopt some technologies from each technology group. This compares to only 40 percent for the middle sized farm units and about 10 percent for the smallest farms. The economic advantages from the technologies are expected to accrue to early adopters, and a large proportion of large farms are anticipated to be early adopters.

Policies Effective in Achieving a Structure

Commodity policy and tax policy are the two broad categories of policy which are expected to be most effective in achieving a particular size distribution of farms. Consensus of the ASG is that specific policies under these two policy categories could be designed to either enhance or to slow the historical trend toward fewer but larger production units.

Background Paper No. 6

Environmental and Natural Resource Impacts of Emerging Technologies in American Agriculture

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ENVIRONMENTAL AND NATURAL RESOURCE IMPACTS OF EMERGING TECHNOLOGIES IN AMERICAN AGRICULTURE *

James Hite

I. Introduction

American agriculture is poised on the threshold of another technological revolution. The revolutions of the past were based on mechanical technologies and on hybrid seed. That about to unfold will be based on biotechnology and computer applications.

Historically, new technologies have often had unforeseen impacts upon the environment and upon natural resource use. In many instances, those impacts have been perceived as negative. If the impacts can be foreseen, however, there is a possibility that the new technologies can be managed so as to mitigate negative environmental and resource impacts.

The purpose of this paper is to evaluate the implications for the environmental and natural resource use of emerging technologies in agriculture. The paper is divided into five parts. The methodology for identifying the emerging technologies and evaluating their environmental/resource impacts is reviewed. Evaluations of each of the technologies is then presented and discussed. Some of the limitations associated with the evaluations are discussed. The relationship between farm size and structure and the adoption of the new technologies is examined. Finally, policies for mitigating the adverse consequences and enhancing the favorable aspects of the new technologies are discussed.

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*Paper based on a workshop conducted by the U.S. Office of Technology Assessment, Washington, D.C., November 15-16, 1984.

II. Methodological Approach

The U.S. Office of Technology Assessment, at the request of five Congressional committees, undertook a study of the policy implications of emerging technologies in American agriculture. Leading agricultural scientists in the private sector, public agencies, and academia were commissioned to review major developments in their fields of work that were likely: 1) to produce new technologies applicable to agriculture; and 2) to be adopted before the end of the twentieth century.

The technologies evaluated in this paper are based on the 28 fields of inquiry represented by these scientists. Those fields and the emerging technologies associated with each are shown in Table 1.

One problem that arises in identifying the technologies to be evaluated is establishment of a time horizon. Although one of the criteria used in identifying the technologies described in the 28 papers discussed above was the possibility of their adoption before the end of the century, some are expected not to be adopted until very late in the century. Even then, adoption may be rather limited and widespread adoption may not occur until the first decade of the next century. The environmental and resource impacts of such technologies may not manifest themselves until early in the next century.

For purposes of public policy, holding rigidly to the end of the century as a time horizon for evaluation of the emerging technologies makes little sense. The policy concerns focus on technologies that should be discouraged or encouraged because of expected environmental/resource consequences. Therefore, the convention used in determining which technologies to be evaluated was that the technology be <u>available</u> for adoption by the end of the century. If the technology was not expected to become available for adoption by the end of the

Table 1. Identification of Emerging Technologies in Agriculture, 1984

Technology	Basic Feature(s)
1. Genetic Engineering in Plants	Recombinant DNA, cell culture, cell fusion, embryo transfers, monoclonal antibodies
2. Enhanced Photosynthesis	Microcomputer crop monitoring, plant breeding
3. Plant Growth Regulators	Organic chemical compounds
4. Plant Disease and Nematode Control	Genetic engineering, holistic management programs
5. Insect and Mite Management	Chemical compounds, genetic manipulation, information processing
6. Weed Control	Biocontrol agents, allelopathic chemicals
7. Biological Nitrogen Fixation	Genetic engineering
8. Chemical Fertilizers	No new technology, use affected by energy prices
9. Water and Soil/Water Plant Relations	Genetic engineering, irrigation procedures
10. Soil Erosion, Productivity and Tillage	Reduced, minimum and no-tillage
11. Multiple Cropping	Plant breeding, changed tillage and harvesting machinery
12. Organic Farming	Nitrogen self-reliance, organic insect control
13. Genetic Engineering in Animals	Recombinant DNA, monoclonal antibodies, embryo transfers
14. Animal Growth Regulation	Genetic engineering, animal monitoring
15. Animal Disease Control	Diagnostic testing, selective breeding, genetic engineering, data management and systems analysis

Table 1. Indentification of Emerging Technologies in Agriculture, 1984 (continued)

Technology	Basic Feature(s)
16. Livestock Pest Control	Slow-release insecticides, vaccines, integrated systems
17. Animal Reproduction	Estrous cycle regulation, embryo transfers
18. Animal Nutrition	Biotechnology, aquaculture
19. Environment and Animal Behavior	Photoregulation, energy conservation, stress control
20. Crop Residue and Animal Waste Use	Chemical and biological conversion, recycling, fuel production
21. Communications and Information Management	Computer systems
22. Monitoring and Control: Plants	Sensors, actuators, computers
23. Monitoring and Control: Animals	Sensors, actuators, computers
24. Telecommunications	Computers, fiber optics, remote sensing
25. Labor Saving	Robot farming, mechanized fruit and vegetable farming
26. Engine and Fuels	Adiabatic compression ignition, electronic engine controls, alternate fuels
27. Crop Separation, Cleaning and Processing	Sensors and control systems
28. Land Management	Conservation tillage, controlled traffic farming, customed prescribed tillage, multiple cropping, organic farming

SOURCE: U.S. Office of Technology Assessment, SUMMARY OF TECHNOLOGY PAPERS, August 1984.

century, it was not considered. However, if it was expected to become available very late in the century, it was considered even though the environmental and resource impacts may not occur until early in the next century.

The Delphi approach has provided the principal technique to evaluate the impacts of emerging technologies (Coates, in Teich, pp. 239-240; Gordon and Ament, in Teich, pp. 171-189). While the technique does not provide for a high level of scientific rigor, the difficulties inherent in foreseeing the myriad of possible consequences of new technology in a complex socio-economic system require subjective evaluation from a well-informed, multidisciplinary team. The Delphi technique lends itself to idenification of any concensus that may exist among experts.

A team of eleven experts was assembled to perform the evaluation. These experts represent a broad range of backgrounds and regions within the United States. The names, affiliations, and disciplinary speciality of each member of the team is included in Appendix A.

The first task of the team was to group the technologies in a way that was meaningful for evaluation of their environmental/resource impacts. The first division was between animal and plant agriculture.

Four general types of technologies related to animal agriculture were identified: 1) genetic engineering, growth, reproduction and nutrition; 2) animal disease, pest control, environment and behavior; 3) animal waste and crop residues; and 4) aquaculture.

Nine general areas of technologies related to plant agriculture were identified: 1) genetic engineering in plants; 2) photosynthesis; 3) nitrogen fixation; 4) chemical fertilizers; 5) organic farming; 6) multiple cropping; 7) water and soil-water plant relationships; 8) soil erosion and land management; 9) disease, insect and weed control.

Each general area of technology was evaluated relative to nine types of impacts: 1) water quality; 2) water quantity; 3) soil erosion; 4) soil productivity; 5) air quality; 6) noise; 7) wildlife; 8) solid waste; and 9) human health.

Evaluation was performed on a ten-point scale. A technology with a strongly favorable impact upon the environment and(or) natural resources would received a rating of 10.0. A technology with a strongly adverse impact would receive a rating of zero. If the impact wered judge to be neutral, the rating would be 5.0.

A computer-driven device called a "Concensor" was used as an aid to tabulating the ratings assigned by each expert. In addition to providing a means for each expert to register a rating, the device also allows each expert to weight his or her rating according to the degree of confidence he or she had in their rating. That level of confidence could be set at zero, 25, 50, 75 or 100 percent.

The Consensor provided an immediate video screen readout of the rating distribution, the weighted average rating, and the average degree of confidence. If the first vote showed a very wide distribution on ratings, those experts with ratings that were outliers were asked to explain their reasons for the ratings assigned. After additional discussion, another vote was taken. Since lack of a concensus after such discussion is, in itself, an indication of considerable uncertanity about the impacts of new technology, no attempt was made to force a consensus beyond a second vote.

The "With and Without Test" was adopted as a basic guide in making the judgements necessary to assign a rating. Very simply, the test involves evaluation of what the environmental/resource situation would

be without the technology and what with the technology. The rating is, therefore, based on an assessment of the net effect of the emerging technology. A rating that suggests that a particular technology will result in environmental improvement cannot be taken to mean that the environment will be better after adoption of that technology than before. Rather, such a rating means that the judgement is the environment will be better with the new technology than it would have been if the old technology were continued into the future. The converse is also true.

III. Results of Evaluation

The results of the panel's assessment are presented in Tables 2-13. Each area of technology is discussed below.

Animal Agriculture - Genetic Engineering, Growth, Reproduction and Nutrition:

The emerging technologies in this area center on recombinant DNA, monoclonal antibodies, estrous cycle regulation and embryo transfer. All of these technologies are expected to lead to production of more output with fewer animals and less input of feed. That means that future demand can be met with fewer animals, less land devoted to production of feed grains and to pasture, and in general, less demand on natural resources, than would otherwise be the case.

On the other hand, the panel was concerned about the effect these new technologies might have on the structure of animal agriculture. If the new technologies were to induce fewer, but larger herds and greater geographic concentrations of animal agriculture, localized environmental problems might intensify.

The results of the ratings by the panel are shown in Table 2. Only

two of the nine environmental impacts were judged relevent to this group of technologies --- water quality and human health. Given fewer animals, the panel concluded that some marginal improvement in water quality would result. The possibilities for using genetic engineering techniques to reduce unsaturated fats in red meats also caused the panel to conclude that these technologies would have a marginally beneficial effect on human health.

Table 2 . Assessment of Environmental and Resource Impacts of Emerging Technologies in Agriculure

Technology Group: ANIMAL AGRICULTURE - GENETIC ENGINEERING, GROWTH, REPRODUCTION AND NUTRITION

Impact on	Rating of Impact *
Water Quality	5.9
Water Quantity	NR
Soil Erosion	NR
Soil Productivity	NR
Air Quality	NR
Noise	NR
Wildlife	NR
Solid Waste	NR
Human Health	5.5

* Rating System: 0 = very adverse impact; 10 = very favorable impact; 5 = neutral impact.
NR = not relevent.

Table 3 . Assessment of Environmental and Rescurce Impacts of Emerging Technologies in Agriculure

Technology Group: ANIMAL AGRICULTURE - DISEASE AND PEST CONTROL, ENVIRONMENT AND BEHAVIOR

Impact on	Rating of Impact *
Water Quality	5.9
Water Quantity	NR
Soil Erosion	NR
Soil Productivity	NR
Air Quality	NR
Noise	NR
Wildlife	NR
Solid Waste	NR
Human Health	5.5

* Rating System: 0 = very adverse impact; 10 = very favorable impact; 5 = neutral impact.
NR = not relevent.

The panel considered very carefully the potential impacts of these new technologies on water quantity, but concluded that they were likely to be insignificant. While the new technologies should reduce the need for feed grains, irrigated acerage accounts for a relatively small percentage of feed grain production, The technologies, therefore, are not expected to have much impact on the demand for irrigation water.

Animal Disease, Pest Control, Environment and Behavior:

The emerging technologies in this area combined biotechnology and computer systems. In addition, it is expected that greater use will be made of existing technologies regarding diagnostic testing, slow-release insecticides and vaccines, and photoregulation.

The panel viewed these technologies as similiar in their effects on production to those associated with animal reproduction, growth, etc. The result is more output of animal products with fewer inputs of natural resources, and the environmental/resource conseqeunces were judged to be essentially the same as those determined with regard to animal reproduction, growth, etc. Hence, the ratings assigned in Table 3 mirror those assigned in Table 2.

Animal Waste and Crop Residue:

The basic features of emerging technologies in the handling of animal waste and crop residues center on chemical and biological conversion; recycling, and fuel production. All of these technologies are already being used to varying degrees. The new features involve increased adoption and application of the technologies to specific crops. One example is use of corn cobs as fuel in thermal gasifers for drying.

Table 4 . Assessment of Environmental and Resource Impacts of Emerging Technologies in Agriculure

Technology Group: ANIMAL AGRICULTURE - ANIMAL WASTE AND CROP RESIDUES	
Impact on	Rating of Impact *
Water Quality	5.4
Water Quantity	NR
Soil Erosion	-5.0
Soil Productivity	NR
Air Quality	5.3
Noise	NR
Wildlife	NR
Solid Waste	NR
Human Health	NR

* Rating System: 0 = very adverse impact; 10 = very favorable impact; 5 = neutral impact.
NR = not relevent.

In general, however, the panel agreed that economic factors will prevent widespread use of biomass for fuel or the conversion of animal waste to methane for the foreseeable future. Incorporating crop residues into the soil is expensive and often creates disease and insect problems. Only if burning of crop residues in the field is banned by law, thus raising the cost of conventional methods of managing these residues, would many of the new technologies in this area be widely adopted.

Assuming the new technologies are adopted, however, the panel arrived at the concensus regarding the environmental/resource impacts as indicated by the ratings presented in Table 4. Increased used of animal waste for energy would reduce some water pollution and the panel foresaw a marginal improvement in water quality from the technology. If crop residues are removed from the fields in large quantities, some additional soil erosion would result, but it was thought that the new technologies would not have much effect on residues left in the field. Any movement toward less burning of crop residues, however, would produce a marginal improvement in air quality in selected localities.

Aquaculture:

One of the papers reviewing emerging technologies dwelt very briefly on aquaculture. The panel thought that the topic was not sufficiently developed and considerable discussion took place regarding aquaculture. Aquacultural activities have considerable potential for impacts on water quality and quantity. In some parts of the country, aquacultural enterprises remove very large quantities of ground water from the aquifers. In addition, there is some potential that waste water from such enterprises will pose a water quality problem.

Table 5 . Assessment of Environmental and Resource Impacts of Emerging Technologies in Agriculure

Technology Group: PLANT AGRICULTURE - GENETIC ENGINEERING

Impact on	Rating of Impact *
Water Quality	6.4
Water Quantity	6.9
Soil Erosion	6.5
Soil Productivity	7.4
Air Quality	5.9
Noise	NR
Wildlife	6.3
Solid Waste	5.4
Human Health	6.1

* Rating System: 0 = very adverse impact; 10 = very favorable impact; 5 = neutral impact.
NR = not relevent.

Yet important economic questions exist regarding the potential growth in markets for aquacultural products. Until those questions are answered, it is not possible to make meaningful comments about potential environmental/resource impacts. The panel raised some warning flags, but no ratings were assigned.

Plant Agriculture - Genetic Engineering:

While the technology of genetic engineering in plants offers dramatic possibilities for agriculture, the scientists working in the area believe that actual adoption of new technologies on the farm is some years away. Basic work in developing gene maps for plants is somewhat behind that for animals.

The technology involves recombinant DNA, cell culture, cell fusion, and monoclonal antibodies. Much of the effort will focus on moisture and drought stress in plants, suggesting less need for irrigation water. There should also be reductions in the use of fertilizers and chemicals as resistances are engineering into plants, with favorable results for water quality. Increased yields will allow retirement of some marginal, erosion-prone land, increasing habitat for wildlife. The possibilities of using genetic engineering techniques to improve soil microbes was thought especially promising for soil productivity. On balance, therefore, the panel thought these genetic engineering techniques in plant agriculture would be rather strongly environmental enhancing. The ratings are presented in Table 5.

Plant Agriculture - Enhanced Photosynthesis:

Photosynthesis is the natural process that makes agriculture possible. Technologies that would enhance photosynthesis, thus, would address the central productive process, increasing yields per unit of

Table 6 . Assessment of Environmental and Resource Impacts of Emerging Technologies in Agriculure

Technology Group: PLANT AGRICULTURE - ENHANCED PHOTOSYNTHESIS

Impact on	Rating of Impact *
Water Quality	6.2
Water Quantity	6.2
Soil Erosion	6.3
Soil Productivity	5.0
Air Quality	NR
Noise	NR
Wildlife	5.6
Solid Waste	NR
Human Health	NR

* Rating System: 0 = very adverse impact; 10 = very favorable impact; 5 = neutral impact.
NR = not relevent.

land. The technologies would allow marginal lands to be retired, water needs could be held down, and there would be less erosion.

The ratings for environmental/resource impacts associated with enhanced photosynthesis technologies are presented in Table 6. In general, the panelists had no difficulty reaching a concensus that the technologies would be environmentally enhancing. One possible exception was noted, however. That exception concerns soil productivity. Enhanced photosynthesis implies that crops on land left in production will be drawing out soil nutrients faster than otherwise would be the case. On those lands, therefore, the effect of the technologies might be to reduce the natural productivity of the soils. There would be less land in production, however, and on those lands, soil productivity would be restored, or at least maintained. On balance, the panel thought that the effect of enhanced photosyntheis technologies on soil productivity would be about neutral.

Plant Agriculture - Nitrogen Fixation:

Legumes have the ability to take nitrogen from the atmosphere and transform it into plant food. In general, the plants used for major cereal crops lack this ability. Breeding cereal plants with nitrogen fixing abilities has long been the Holy Grail of agricultural geneticists, but many very difficult problems have been encountered. Advances in genetic engineering, however, have opened up new avenues for plant breeders and there is renewed hope of developing cereal plants with nitrogen fixing capabilities. While the possibilities for significant breakthroughs prior to the end of the century are considered remote, some incremental advances are expected.

Table 7 . Assessment of Environmental and Resource Impacts of Emerging Technologies in Agriculure

Technology Group: PLANT AGRICULTURE - NITROGEN FIXATION

Impact on	Rating of Impact *
Water Quality	7.1
Water Quantity	NR
Soil Erosion	NR
Soil Productivity	5.6
Air Quality	5.4
Noise	NR
Wildlife	6.3
Solid Waste	NR
Human Health	5.9

* Rating System: 0 = very adverse impact; 10 = very favorable impact; 5 = neutral impact.
NR = not relevent.

Should nitrogen fixing technologies develop, the environmental/resource implications would be significant and positive. These technologies would allow substantial reductions in use of chemical fertilizers. As a result, there would be less nitrogen runoff into surface waters and percolation into groundwater, with beneficial effects on water quality. With less nitrogen being manufacturered, fewer people are exposed to health risks in fertilizer plants and on the farm. Improved air quality would result from reduced fertilizer manufacturing and wildlife, especially aquatic life, would benefit from reduction of nitrogen runoff into surface waters.

Plant Agriculture - Growth Regulation:

Plant growth regulators are typically organic chemical compounds applied to the surface of the plants by spraying. Chemical concentration in the sprays is usually quite low. The compounds are rather quickly metabolized by the lands and usually present few environmental problems because the compounds themselves tend to break down quickly. The effect is increased yield by affecting the way the plant uses the same amount of nutrients.

The panel decided that the environmental/resource impacts of new technologies in plant growth regulation were likely to be quite similar to those determined for enhanced photosynthesis. The ratings assigned and presented in Table 8 mirror those presented in Table 6.

Table 8 . Assessment of Environmental and Resource Impacts of Emerging Technologies in Agriculure

Technology Group: PLANT AGRICULTURE - GROWTH REGULATION

Impact on	Rating of Impact *
Water Quality	6.2
Water Quantity	6.2
Soil Erosion	6.3
Soil Productivity	5.0
Air Quality	NR
Noise	NR
Wildlife	5.6
Solid Waste	NR
Human Health	NR

* Rating System: 0 = very adverse impact; 10 = very favorable impact; 5 = neutral impact.
NR = not revelent.

Plant Agriculture - Organic Farming:

In some sense, organic farming represents not a new, but an old and traditional set of technologies. However, in recent years, the concept of organic farming has undergone some changes. At the heart of organic farming are technologies concerned with nitrogen self-reliance and minimum use, but not necessarily total elimination of chemicals. Particularly, the new organic farming could be expected to make use of advances flowing from genetic engineering and enhanced photosynthesis, simultaneous cropping, and several of the other technologies dicussed seperately in this paper.

Assessing the environmental/resource implication of organic farming presented more problems for the panel than any other single set of technologies. While there was general agreement that organic farming approaches would require more land than currently being used to meet expected demand, there was skepticism about the extent to which organic farming technologies would be adopted. Organic farming, should it be widely adopted, would disperse animal agriculture geographically since there would be a greater need to keep animals on every farm to obtain manures. Should energy prices rise substantially, organic farming techniques might be adopted rather widely, but barring such rises in energy prices, the panel thought it unlikely that organic farming would account for more than a small percentage of the nation's farm output.

The panel showed some reservations about the environmental/resource impacts of organic farming should it be widely adopted. Increased pressures would be brought on marginal and erodable lands, and widespread use of animal manures could have some negative consequences for water and air quality. While wildlife might be less threatened by chemical compounds, the area of wildlife habitat would be attacked by the

Table 9 . Assessment of Environmental and Resource Impacts of Emerging Technologies in Agriculure

Technology Group: PLANT AGRICULTURE - ORGANIC FARMING

Impact on	Rating of Impact *
Water Quality	5.7
Water Quantity	5.1
Soil Erosion	5.6
Soil Productivity	5.5
Air Quality	NR
Noise	NR
Wildlife	5.5
Solid Waste	5.5
Human Health	5.9

* Rating System: 0 = very adverse impact; 10 = very favorable impact; 5 = neutral impact.
NR = not relevent.

need for more land in crops. The strongest positive impact was thought to be perhaps in the area of human health. Organic farming would reduce exposure to agricultural chemicals and potentially could result in food products that have higher nutritional value. However, the confidence levels on the ratings presented in Table 9 are quite low.

Plant Agriculture - Multiple Cropping:

The concept of multiple cropping actually involves two separate types of practices. The first might better be called "simultaneous cropping," and it involves growing two or more crops in the same field at about the same time. The second type involves following one crop closely behind another in the same field in the same year. The two types merge in some cases where one crop is begun before the other is harvested out of a field.

The latter type of multiple cropping has been increasing rather rapidly in the Southeast and in California. Because the land is covered with a crop for longer periods during the year, there is less erosion and less runoff, with favorable results both for water quality and for soil conservation. In some areas, however, more irrigation water is required. Multiple cropping can be either beneficial or harmful to soil productivity, depending upon the crops being grown. In the wheat-soybean systems of the Southeast, for instance, some panelists thought that multiple cropping might improve soil productivity marginally, but other systems would intensify the removal of soil nutrients.

The panel reasoned that multiple cropping would probably have, on balance, some adverse conseqeunces for wildlife. Machinery would be in the fields more often, disturbing nesting areas and wildlife generally. Also, there would be less stubble and other crop residues available for

Table 10. Assessment of Environmental and Resource Impacts of Emerging Technologies in Agriculure

Technology Group: PLANT AGRICULTURE - MULTIPLE CROPPING

Impact on	Rating of Impact *
Water Quality	6.0
Water Quantity	4.8
Soil Erosion	6.8
Soil Productivity	5.0
Air Quality	NR
Noise	NR
Wildlife	4.8
Solid Waste	NR
Human Health	NR

* Rating System: 0 = very adverse impact; 10 = very favorable impact; 5 = neutral impact.
NR = not relevent.

cover and feed. On the otherhand, however, multiple cropping has the potential to reduce the land needs of agriculture and, as a result, to protect habitat.

Plant Agriculture - Water and Soil/Water/Plant Relationships:

The base scientific paper discussing this area was often vague and caused the panelists some difficulty in trying to define precisely what technologies needed assessment. The area includes genetic engineering approaches to improving the capabilities of plants to retain moisture with closed stamata. The ratings, however, were assigned primarily on perceptions of still-to-be applied irrigation technologies, particularly, improvements in on-the-farm irrigation technologies.

The panel saw movement toward improved irrigation efficiency as environmentally benign. Less water applied means less return flow and less threat to water quality. It also means substantial savings in water and less erosion. The effects on soil productivity are more mixed, however. While improved technologies would allow plants to make better use of existing soil nutrients, they will also allow those nutrients to be used up faster. But nutrients that might otherwise be flushed out will be saved. So, on balance, the panel thought that improved irrigation technologies would have a marginally beneficial effect on soil productivity. Similarly, the effects of wildlife are likely to be mixed. Concentration of salts in runoff water might be higher and, with less water, there might be fewer reservoirs and other habitat. But with less water being drawn away from irrigation, more clean water might be available elsewhere. The panel, thus, determined that the impact on wildlife was probably neutral. Ratings are presented in Table 11.

Table 11. Assessment of Environmental and Resource Impacts of Emerging Technologies in Agriculure

Technology Group: PLANT AGRICULTURE - WATER AND SOIL/WATER/PLANT RELATIONSHIPS

Impact on	Rating of Impact *
Water Quality	6.2
Water Quantity	7.5
Soil Erosion	7.1
Soil Productivity	5.8
Air Quality	NR
Noise	NR
Wildlife	5.0
Solid Waste	NR
Human Health	NR

* Rating System: 0 = very adverse impact; 10 = very favorable impact; 5 = neutral impact.
NR = not relevent.

Plant Agriculture - Soil Erosion/Land Management

One of the major technological changes in agriculture in the 1970's was the growth of what is called "conservation tillage." Conservation tillage implies limited tillage. It has several forms. In some cases, corn and other grains are actually planted into grass or stubble, with an herbicide applied in a very narrow strip where the seed is injected. A newer innovation is called "prescribed tillage," a practice that involves use of computer technology to monitor soil conditions and integrates such information with weather forecasts, etc. to determine when and how to undertake tillage.

Conservation tillage has enormous possibilities to reduce soil erosion. The major environmental problem relates to increased use of herbicides and to lower yields, implying increased acreage to meet given demand. Nevertheless, as indicated by the ratings in Table 12, the panel showed real enthusiasm about the environmental/resource impacts of this set of technologies. The panel did make a deliberate effort to raise a caution flag, however, by assigning a neutral score to the human health impact. Some members argued strongly that the health impact was likely to be negative because of increase threat to groundwater from agricultural chemicals, but others thought that reduced tillage, and reduced opportunities for farm accidents associated with tillage activities, needed to be thrown on to the scales.

Plant Agriculture - Disease, Insect and Weed Control:

The emerging technologies in this area begin with integrated pest management (IPM), an approach to pest control that does not eliminate use of pesticides, but does attempt to minimize those pesticides by making maximum use of predators, attempting to protect beneficial

Table 12. Assessment of Environmental and Resource Impacts of Emerging Technologies in Agriculure

Technology Group: PLANT AGRICULTURE - SOIL EROSION/LAND MANAGEMENT

Impact on	Rating of Impact *
Water Quality	6.3
Water Quantity	6.6
Soil Erosion	9.1
Soil Productivity	7.7
Air Quality	6.6
Noise	NR
Wildlife	6.7
Solid Waste	NR
Human Health	5.1

* Rating System: 0 = very adverse impact; 10 = very favorable impact; 5 = neutral impact.
NR = not relevent.

insects, and applying pesticides in limited quantities only after no other control mechanism is deemed feasible. IPM has the potential to reduce pesticide use by as much as 50 percent.

Integrated weed management is similiar in concept. Changes in cultivation practices are integrated into reduced use of herbicides.

While these new technologies, combined with a new generation of agricultural chemicals expected to appear on the market by late in the decade, will tend to cause environmental improvements over existing technologies if properly applied, some skepticism was expressed by members of the panel concerning application in the field. Application machinery often is not precise, and knowing that, farmers sometimes deliberately use a greater application rate than called for on labels. While most panelists tend to give these new technologies ratings above five, there was considerable spread in the ratings in most impact areas. Unlike many of the other technologies examined, the panel did not see these disease, insect and weed control technologies having much impact on the quantity of land in crops, and most of the environmental improvements are expected to be associated with reduced use of agricultural chemicals.

IV. Limitations and Caveats

Recapitulation:

Looking at all the technologies assessed, the panel considered that the environmetal/resource impacts were likely to be, at least marginally, environmentally enhancing. Particularly, they noted the potential for new tillage technologies to reduce soil erosion and improve soil productivity, for new irrigation technologies to conserve water, for nitrogen-fixing technologies to improve water quality, and for genetic

Table 13. Assessment of Environmental and Resource Impacts of Emerging Technologies in Agriculure

Technology Group: PLANT AGRICULTURE - DISEASE, INSECT AND WEED CONTROL

Impact on	Rating of Impact *
Water Quality	6.9
Water Quantity	5.3
Soil Erosion	7.0
Soil Productivity	5.7
Air Quality	5.7
Noise	NR
Wildlife	7.1
Solid Waste	-6.1
Human Health	7.4

* Rating System: 0 = very adverse impact; 10 = very favorable impact; 5 = neutral impact.
NR = not relevent.

engineering to improve soil productivity. The technologies should reduce land needs and thereby reduce threats to wildlife habitat. They should also reduce use of chemicals and reduce resulting threats to human health.

In only a few cases did a concensus emerge that the new technologies were likely to have unfavorable environmental or resource impacts. Those concern the impacts of multiple cropping on water quality and on wildlife. In both these cases, however, the unfavorable impacts were thought to be relatively mild.

Yet a number of individual panelists did express reservations about the impacts of various technologies. Concern arose over possible problems associated with human error or machine malfunction in application of chemicals used in conservation tillage. Widespread adoption of organic farming was thought a potential problem because of its implications regarding the land needs of agriculture.

Perhaps the chief cause for concern was lack of knowledge about potential effects on the environment resulting from release of genetically-altered organisms. Most of the biotechnologies applicable to agriculture that are expected to be commercially adopted in the next few years do not involve release of new organisms into the ambient environment. The question of "deliberate release" of micro-organisms has already arisen in agriculture, however, in connection with testing of genetically-altered bacteria in potato fields to prevent freeze damage. Other cases are almost certain to arise. The potential for these genetically-altered micro-organisms to interact with the environment in unpredictably harmful ways cannot be ignored. Considerable debate is occuring within the scientific community and within the federal bureaucracy over proper controls on the testing and use of genetically-altered

organisms before deliberate release. The economic benefits from uses of biotechnology requiring deliberate release of modified organisms are substantial, but the panel recognized the need to work out suitable regulatory safeguards controlling such releases (See Doyle, Healy, Kendrick, Schatzow).

Limitations of Evaluation:

The concern over possible undesirable environmental consequences resulting from deliberate release of genetically-altered micro-organisms illustrates one type of limitation inherent in the evaluations reported here. A predictive ecology capable of indicating in a specific way the likely consequences of potential uses of biotechnology is simply not available. Possible ecologic scenarios can be speculated about, but it is often difficult to move beyond informed speculation in areas where the technology involves deliberate release of new forms of life.

Another limitation of the panel's evaluations concerns possible indirect environmental effects. Indirect effects are defined as those not from end-use application of the technology in agriculture, but from production of the technological products in manufacturing processes, from transportation, storage, and sales of those products, and from the effects of using the new technology on regional comparative advantage and the demand for labor.

In general, a procedure exists using input-output models that is conceptually capable of evaluating some of these indirect effects. Use of such models in the context of these emerging technologies, however, is not practical because many of the technologies are still too unformed to offer any hint as to how the coefficients in an input-output model will be effected by their adoption. Some of the indirect effects ---

those related to regional comparative advantage and to labor skill needs --- are beyond the capabilities of input-output models.

Nevertheless, indirect effects can be significant. While the direct effects of a new technology may be quite harmful, the indirect effects could be environmentally enhancing. Or vice-versa. Empirical work has shown that the cumulative indirect effects may be significantly larger in magnitude than the direct effects (Hite and Laurent).

An effort was made to have the panel use the Delphi technique to estimate indirect as well as direct effects. That effort proved futile because of the complex lines of causation associated with indirect effects and the inability of individuals to make the thousands of subjective judgements required in any reasonable time period. Consequently, the evaluations presented here focus exclusively on direct effects, and are limited in their relevence to indirect effects to the comments offered by panel members as part of the general discussion of the technology included as part of the text above.

V. Farm Structure and the Environment

After evaluating each of the areas of emerging technologies, the panel was asked to turn its thoughts toward the impact of farm structure on the environment and natural resources. Three scenarios related to three different structures of production agriculture were postulated: 1) a continuation of current policy which could be expected to result, by the end of the century, in a notably bimodal distribution of farms by size --- many small farms with sales of less than $20,000 annually and many large farms with sales of $500,000 or more each year; 2) policies that accelerate the trend toward a bimodal distribution and a significant reduction in the number of medium-sized farms; and 3) policies that

would slow down the move toward the bimodal distribution, maintaining the number of medium sized farms at the expense of the larger farms.

The question posed to the panel was: what effect, if any, would these structural scenarios have on the environment and on natural resource use?

The same scale was used in assigning ratings as was used in evaluating the various sets of technologies. That is, a rating of 5.0 means that the scenario is expected to make no perceptible difference. Ratings higher than 5.0 suggest environmental improvment, *certeris paribus,* whereas ratings below 5.0 suggest some environmental degradation.

In discussing the assignment, the panel focused on considerable evidence suggesting that large farms are more likely to adopt new technologies than small farms. Small farms are constrained by time limitations in use of technologies that require intensive management. They may also be constrained by access to financing. In this context, both are especially important since many of the new technologies both are management intensive and will require substantial frontend financial outlays.

On the other hand, it was noted that some large farms currently may be more heavily leveraged financially than the medium sized farms. Moreover, since almost all of the small farms are operated by persons or families with some outside income, the small farms may be less constrained financially to use technologies that save labor and do not require enormous frontend outlays necessitating borrowing. Organic farming is an example of a technology that may have more appeal to small than to large farmers.

Before presenting the ratings, it is also important to note that many large farms making use of hired labor may concentrate on labor-cost

minimization. The new technologies, in the main, are not primarily labor saving. The principal savings to be had from these new technologies are in land and in environmental degradation. Since the environmental effects are usually offsite and external to the farm firm's accounts, there may be only modest incentives for some of the bigger farms to adopt the new technologies unless under strong regulatory pressures from environmental agencies.

On balance, however, the panel determined that the technologies would favor large operators. Since the technologies, in general, tend to be environmentally enhancing,it follows that movement toward greater concentration of production in the hands of large operators would have beneficial environmental effects.

However, several panelists insisted on the caveat that the major factors influencing adoption of the new technologies are access to frontend capital and managerial capability. Those are not confined exclusively to large farms, but many medium-size farms also are in a position to adopt the technologies. In the areas of animal agriculture, particularly, many of the new technologies are being adopted first by seed-stock producers who tend to be medium-size operators.

All these reservations are important as background for interpretation of the ratings presented in Table 14. Scenario 1 represents a continuation of recent trends and, given the "with and without" rule used in evaluating the technologies, must be assigned a rating of 5.0 (environmentally neutral) in all impact areas. Movement toward greater concentration of production on large farms would, in the judgement of the panel, have a general tendency to enhance the environment because the larger farms (as a class) will be more likely to adopt the new technologies. The panel emphasizes, however, in the strongest possible

Table 14. Assessment of Impact of Farm Structure on Environment Resource

Impact Area	Structure Scenario		
	1	2	3
Water Quality	5.0	6.1	4.2
Water Quantity	5.0	5.1	5.0
Soil Erosion	5.0	5.6	4.6
Soil Productivity	5.0	5.2	4.8
Air Quality	5.0	5.0	5.0
Noise	5.0	5.0	5.0
Solid Waste	5.0	5.0	5.0
Human Health	5.0	5.5	4.6

Rating Scale: 0 = extremely adverse impact; 10 = very favorable impact; 5.0 = neutral impact.

terms, that movement toward greater concentration on large farms is not a necessary condition for realization of environmental improvement flowing from the new technologies. Public policies that improved the access of small and medium-size farms to the new technologies would accomplish the same end.

Scenario 3 represents public policy designed to improve the survival rates of medium-size farms. Such policy, taken alone, was judged to have unfavorable environmental consequences in five of the nine impact areas addressed. If such farms survive, but do not prosper, they will have few resources available to use in adopting the new technologies. Policies that improve the opportunities of medium-size farms to prosper as well as survive, however, would allow them to avail themselves of new technologies that are environmentally enhancing. Indeed, under such conditions, medium-size farms might well adopt these new technologies more rapidly than the larger farms for reasons alluded to in the paragraphs above.

VI. Policy Implications

Although the discussion above addresses obliquely some policy matters, the purpose of this section is to report the panel's discussion of the way that public policy might enhance the positive environmental effects or mitigate the negative effects of the emerging technologies.

The first point on which a concensus emerged centered on the observation that the net movement of new technologies is environmentally enhancing. Given the public pressure for environmental improvement and the increased regulatory activity by government in the environmental area, that movement is consistent with economic theory. It follows, then, that increased government expenditures on research and education

would tend to have positive environmental effects. The assessments presented in this paper suggest that there is a strong public interest in accelerating technological change in agriculture, and if that is the objective, the action required is increased research and education.

The second approach that complements the research and education effort is more stringent environmental regulations and stronger enforcement of regulations. Such regulations tend to have the economic effect of raising the cost of using the environment in agricultural production. Economic theory suggest that as costs of particular inputs are increased, economic agents find ways to reduce the use of the relatively higher priced inputs. So increasing the costs of environmental inputs through stronger regulations and better enforcement will accelerate the adoption of the new technologies and give impetus to research that has further environmental benefits.

Finally, policies that reward farmers who adopt environmentally enhancing technologies have some precedent. Cost-sharing programs in the area of soil conservation are the best known example. Targeted cost-sharing and creative use of the relationship between environmentally enhancing farm practices and the price support program, such as the so-called "cross-compliance" proposal for using conservation cost-sharing funds, represents, at least in a generic way, a policy option likely to enhance the environmental benefits of the new technologies.

Turning to policies to mitigate the undesirable environmental impacts of new technologies, the panel moved quickly to the classic prescription of exacting a user charge. If the research base were available to determine the appropriate "T" value for soil erosion, a soil erosion tax could be levied on each ton of loss above that level. Ideally, the tax would be equal to the environmental damage caused by

the erosion. Unfortunately, the research base for setting the "T" value is not sufficient. There would also be very difficult enforcement problems with such a tax. But the idea of making users of environmental inputs pay for them was considered fundamental to policy to mitigate undesirable environmental consequences.

More practical applications of this concept focus on raising the costs of agricultural chemicals by placing excise taxes on those chemicals. The more expensive the chemicals, the less they will be used and the greater care the user will take to be sure than the application rate is not excessive. Similarly, policies to raise the price of irrigation water might have some beneficial impacts on water quantity (although there are studies suggesting that the price elasticity on such water approximates unity).

VII. Summary and Conclusions

This paper reports on the use of the Delphi technique by a panel of agricultural scientists to evaluate the impacts upon natural resource use and the environment of 13 major new technologies that can be expected to have commercial application in American agriculture by the end of the century. Each technology was evaluated with regard to its expected direct impact on nine resource/environmental areas of concern. Lack of a suitable model and the analytical complexity of the task prevented any systematic evaluation of the indirect impacts of the emerging technologies.

In general, the evaluations tend to be conservative. With a few notable exceptions, most of the technologies are expected to reduce substantially the land and water requirements for meeting future agricultural needs. As a result, these technologies are expected to reduce

environmental problems associated with the use of land and water. The technologies were thought to have beneficial effects relative to soil erosion, to reduce threats to wildlife habitat, and to reduce dangers associated with use of agricultural chemicals. Widespread adoption of organic farming technology, the panel concluded, would probably increase land requirements, however, and thereby increase soil erosion and the threat to wildlife habitat while producing substantial benefits through reduction in use of agricultural chemicals. Similarly, the panel raised a caution flag concerning new tillage technologies that reduce erosion and threats to wildlife while increasing dangers from use of agricultural chemicals.

Perhaps the most revolutionary of the new technologies are those associated with recombinant DNA. While specific applications of such technologies that are currently apparent would appear to reduce resource needs and threats to the environment arising from agricultural activities, the panel recognized possible dangers associated with deliberate release of genetically-altered micro-organisms. The very revolutionary nature of the new biotechnologies, the early stages of research applicable to their use in agriculture, and the lack of a scientifically accepted predictive ecology prevented the panel from providing specific evaluations of resource/environmental impacts associated with deliberate release of new forms of life.

The panel concluded that the new technologies were most likely to received first adoption by farmers who well-financed and are capable of providing the sophisticated management required to make profitable uses of them. In the main, such farmers will tend to be those with relatively large operations. Hence, the technologies will tend give additional

economic advantages to large farm firms relative to middle-sized and smaller farms, accentuating the trend toward a bimodal farm structure in the U.S.

In addition, the panel concluded that since the new technologies tend to be, at the margin, environmental enhancing, there is a public interest in research and education that leads to their rapid and widespread adoption. That conclusion becomes even stronger if public policy is aimed at maintainence of the middle-sized, so-called family farm. Larger farms with their own access to research results and scientific expertise may be able to advance the new technologies with relatively little publicly-sponsored research. But family farmers will need to depend upon publicly-sponsored research and extension education to obtain access to the new technologies and adapt them to their individual situations.

The panel also concluded that the new technologies will require more stringent environmental regulations and stronger enforcement of regulations. The complexities of some of the emerging technologies will pose significant challenges for promulgation of intelligent environmental regulations. The economic benefits from the technologies cannot be passed by, but users may have little private incentive to make use of the technologies in ways that avoid unnecessary adverse third-party effects. The panel considered that economic incentives or disincentives, including the use of excise taxes to discourage overuse of potentially threatening materials, represented a more intelligent approach to protection of environmental values than direct regulations. Yet the panel also concluded that some additional effort to enforce existing regulations would hasten the adoption of the new technologies than are, at least potentially, less envronmental threatening, and that new regula-

tions will be required to deal with some aspects of the emerging technologies.

APPENDIX A

Members of Panel of Experts
Evaluating Impacts of New Technologies

Individual and Affiliation	Speciality Area
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Dr. Clyde Kiker Assoc. Professor of Agricultural Economics McCarty Hall University of Florida Gainesville, Fla. 32601	Economic-Environmental Linkages
Dr. Randall Kramer Department of Agricultural Economics Virginia Polytechnic Institute and State University Blacksburg, Va. 24061	Soil Conservation Economics
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Dr. C. Ford Runge Asst. Professor of Agricultural Economics University of Minnesota St. Paul, Minn. 55108	Natural Resources Policy
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